# EXHIBIT 2

US006242701B1

(12) **United States Patent**
**Breed et al.**

(10) **Patent No.: US 6,242,701 B1**
(45) **Date of Patent: Jun. 5, 2001**

(54) **APPARATUS AND METHOD FOR MEASURING WEIGHT OF AN OCCUPYING ITEM OF A SEAT**

(75) Inventors: **David S. Breed**, Boonton Township, Morris County, NJ (US); **Wilbur E. DuVall**, Kimberling City, MO (US); **Jeffrey L. Morin**, Grosse Ile, MI (US)

(73) Assignee: **Automotive Technologies International, Inc.**, Denville, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/193,209**

(22) Filed: **Nov. 17, 1998**

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 09/128,490, filed on Aug. 4, 1998, now Pat. No. 6,078,854, which is a continuation-in-part of application No. 08/970,822, filed on Nov. 14, 1997, now Pat. No. 6,081,757, and a continuation-in-part of application No. 08/474,783, filed on Jun. 7, 1995, now Pat. No. 5,822,707.

(51) **Int. Cl.**[7] .......... **B60R 21/22**; B60R 21/32; G01G 19/52; G01G 3/14

(52) **U.S. Cl.** .......... **177/144**; 177/210 R; 180/273; 280/735; 701/45

(58) **Field of Search** .......... 177/136, 144, 177/210 R, 254, 211; 180/273; 280/735; 701/45; 340/667

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,275,975 | 9/1966 | King | 180/272 |
| 4,519,652 | 5/1985 | Kamijo | 180/268 |
| 4,625,320 | 11/1986 | Ishikawa | 382/104 |
| 4,645,233 | 2/1987 | Bruse et al. | 280/753 |
| 4,698,571 | 10/1987 | Mizuta et al. | 318/466 |
| 4,811,226 | 3/1989 | Shinohara | 318/466 |
| 5,008,946 | 4/1991 | Ando | 180/167 |
| 5,071,160 | 12/1991 | White et al. | 280/735 |
| 5,074,583 | 12/1991 | Fujita | 280/735 |
| 5,086,652 * | 2/1992 | Kropp | 73/767 |
| 5,090,493 * | 2/1992 | Bergan et al. | 177/211 |
| 5,118,134 | 6/1992 | Mattes | 280/735 |
| 5,125,686 | 6/1992 | Yano | 280/801.2 |
| 5,155,685 | 10/1992 | Kishi et al. | 364/424.05 |
| 5,161,820 | 11/1992 | Vollmer | 280/730 |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

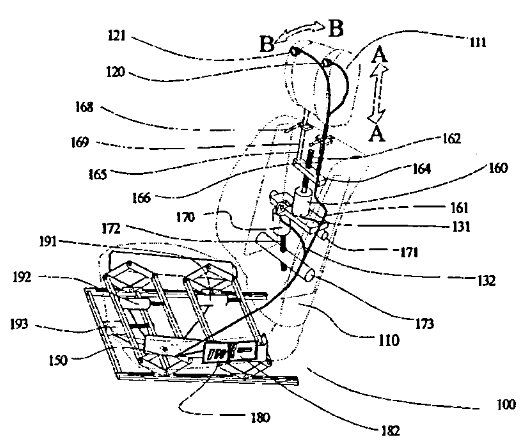
| | | | |
|---|---|---|---|
| 950560 * | 10/1999 | (EP) | 177/144 |
| 2289332 | 11/1995 | (GB) | 280/735 |

*Primary Examiner*—Randy W. Gibson
(74) *Attorney, Agent, or Firm*—Brian Roffe

(57) **ABSTRACT**

An apparatus for measuring the weight of an occupying item of a seat including a support structure for mounting the seat to a substrate. The apparatus includes a strain gage transducer mounted on the support structure and arranged to provide a measurement of the strain of the support structure at the location at which it is mounted. A control system is coupled to the strain gage transducer for determining the weight of the occupying item of the seat based on the strain of the support structure measured by the strain gage transducer. The weight measuring apparatus is used in a seat adjustment apparatus for adjusting a seat in a passenger compartment of a vehicle including wave sensors for transmitting waves into the passenger compartment toward the seat, receiving reflected waves from the passenger compartment and generating an output representative of the reflected waves received by the wave sensors, and a processor for receiving the outputs from the wave sensors and the weight measuring apparatus and evaluating the seated-state of the seat based thereon. The processor, e.g., directs a control unit to cause a portion of the seat to move based on the evaluation of the seated-state of the seat or to affect the deployment of an airbag.

**40 Claims, 30 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 5,222,399 | * | 6/1993 | Kropp | 73/862.68 |
| 5,232,243 | | 8/1993 | Blackburn et al. | 280/735 |
| 5,254,924 | | 10/1993 | Ogasawara | 364/424.05 |
| 5,330,226 | | 7/1994 | Gentry et al. | 280/735 |
| 5,377,108 | | 12/1994 | Nishio | 701/45 |
| 5,413,378 | | 5/1995 | Steffens, Jr. et al. | 280/735 |
| 5,439,249 | | 8/1995 | Steffens, Jr. et al. | 280/735 |
| 5,454,591 | | 10/1995 | Mazur et al. | 280/735 |
| 5,474,327 | | 12/1995 | Schousek | 280/735 |
| 5,531,472 | | 7/1996 | Semchena et al. | 280/735 |
| 5,573,269 | | 11/1996 | Gentry et al. | 280/735 |
| 5,583,771 | | 12/1996 | Lynch et al. | 701/45 |
| 5,653,462 | | 8/1997 | Breed et al. | 280/735 |
| 5,670,853 | | 9/1997 | Bauer | 318/286 |
| 5,694,320 | | 12/1997 | Breed | 364/424.055 |
| 5,702,123 | | 12/1997 | Takahashi et al. | 280/735 |
| 5,714,695 | * | 2/1998 | Bruns | 177/211 |
| 5,748,473 | | 5/1998 | Breed et al. | 364/424.055 |
| 5,785,347 | | 7/1998 | Adolph et al. | 280/735 |
| 5,822,707 | | 10/1998 | Breed et al. | 701/49 |
| 5,991,676 | * | 11/1999 | Podoloff et al. | 701/45 |
| 6,015,163 | * | 1/2000 | Langford et al. | 280/735 |
| 6,039,344 | * | 3/2000 | Mchney et al. | 280/735 |
| 6,069,325 | * | 5/2000 | Aoki | 177/138 |
| 6,087,598 | * | 7/2000 | Munch | 177/144 |
| 6,104,100 | * | 8/2000 | Neuman | 307/10.1 |

* cited by examiner

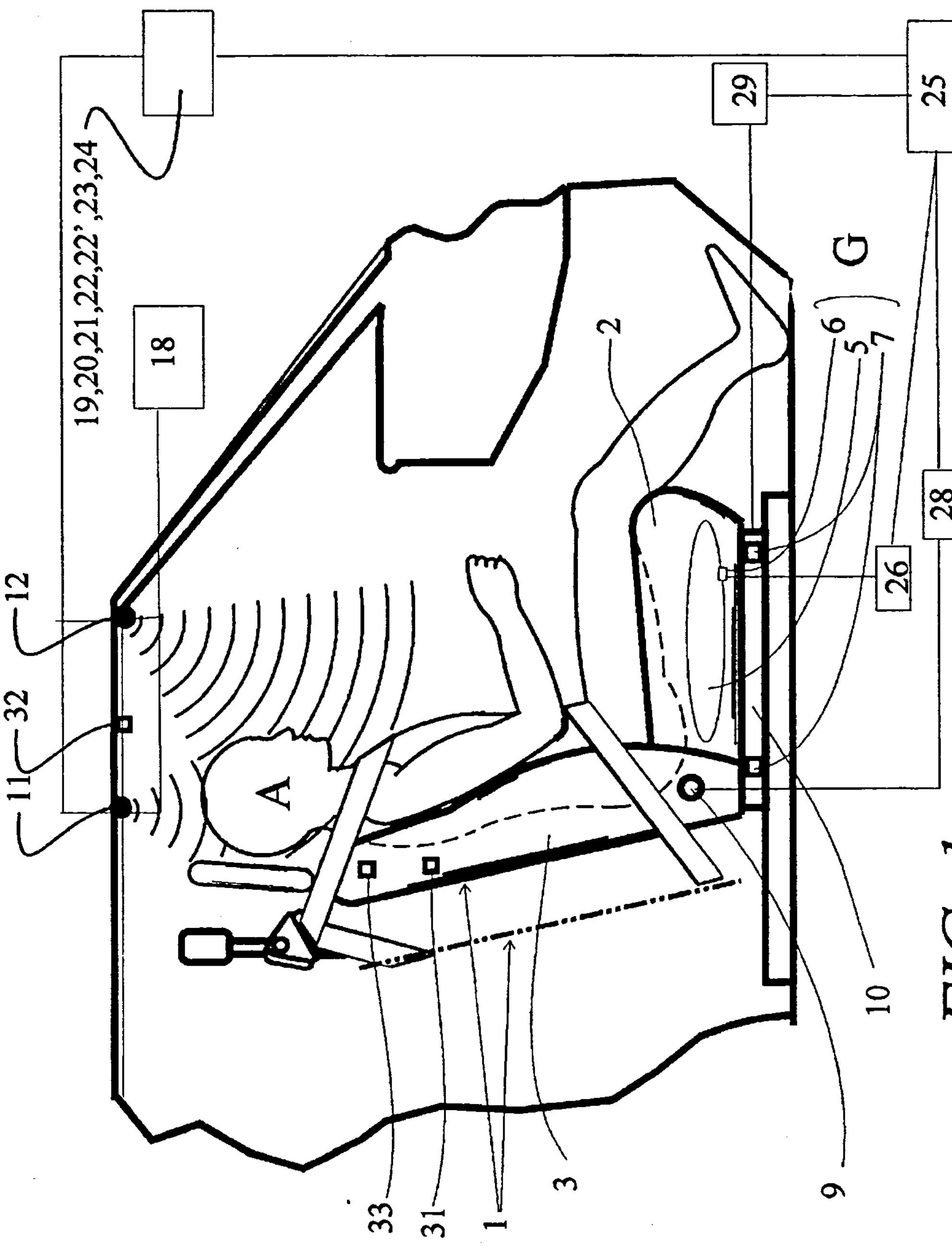



FIG. 1

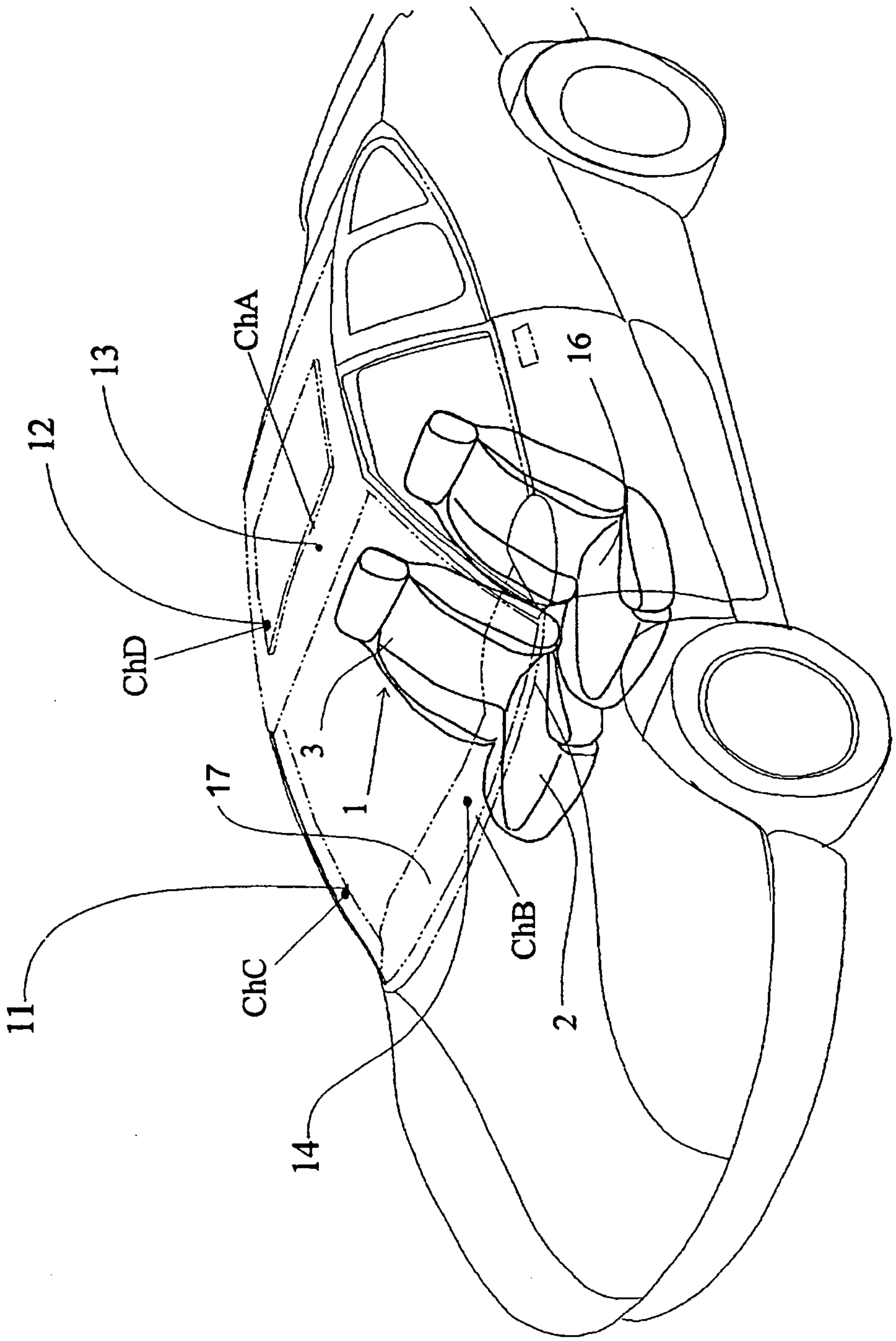



FIG. 2

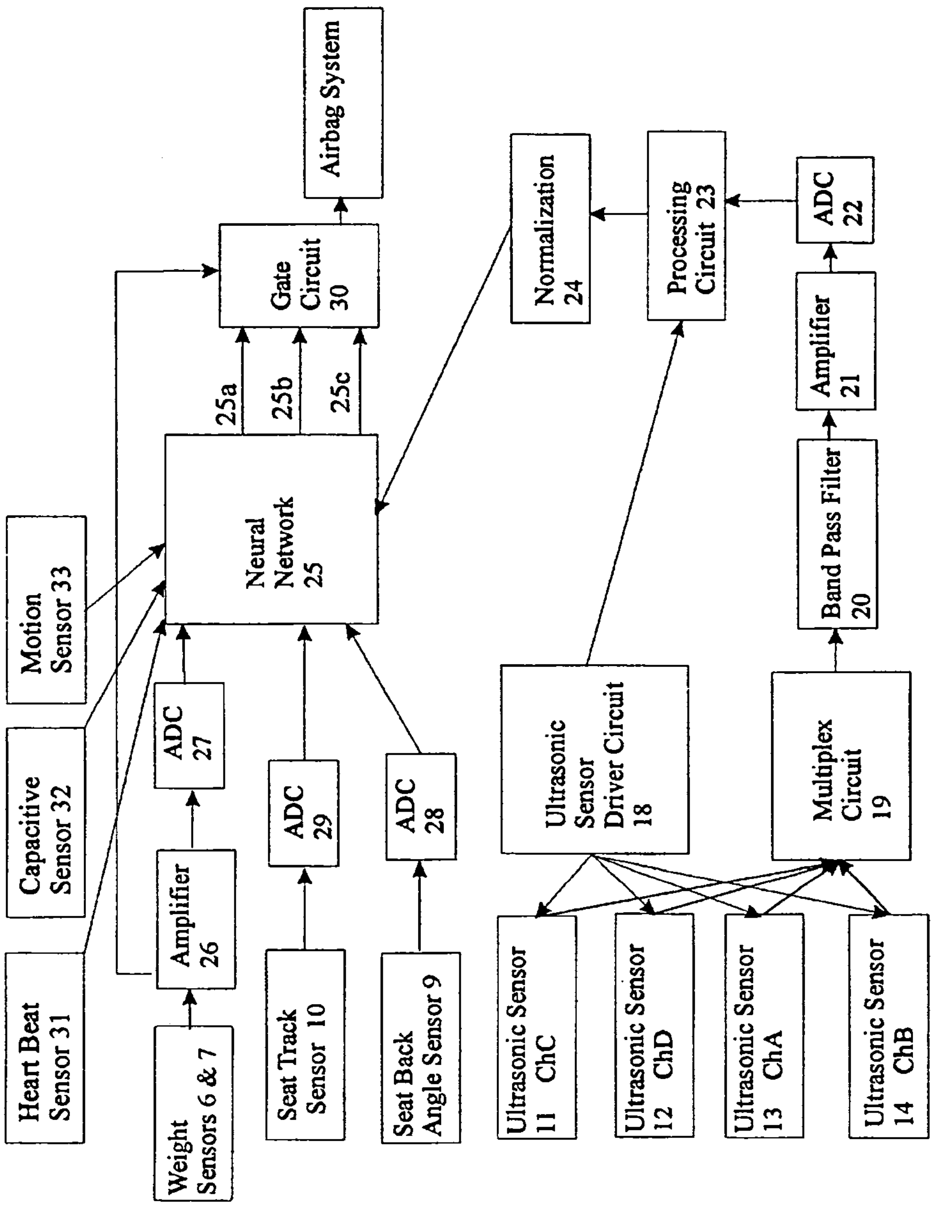

Airbag System
Gate Circuit 30
Normalization 24
Processing Circuit 23
ADC 22
25a
25b
25c
Amplifier 21
Neural Network 25
Band Pass Filter 20
Motion Sensor 33
Capacitive Sensor 32
ADC 27
ADC 29
ADC 28
Ultrasonic Sensor Driver Circuit 18
Multiplex Circuit 19
Heart Beat Sensor 31
Amplifier 26
Weight Sensors 6 & 7
Seat Track Sensor 10
Seat Back Angle Sensor 9
Ultrasonic Sensor 11 ChC
Ultrasonic Sensor 12 ChD
Ultrasonic Sensor 13 ChA
Ultrasonic Sensor 14 ChB

FIG. 3

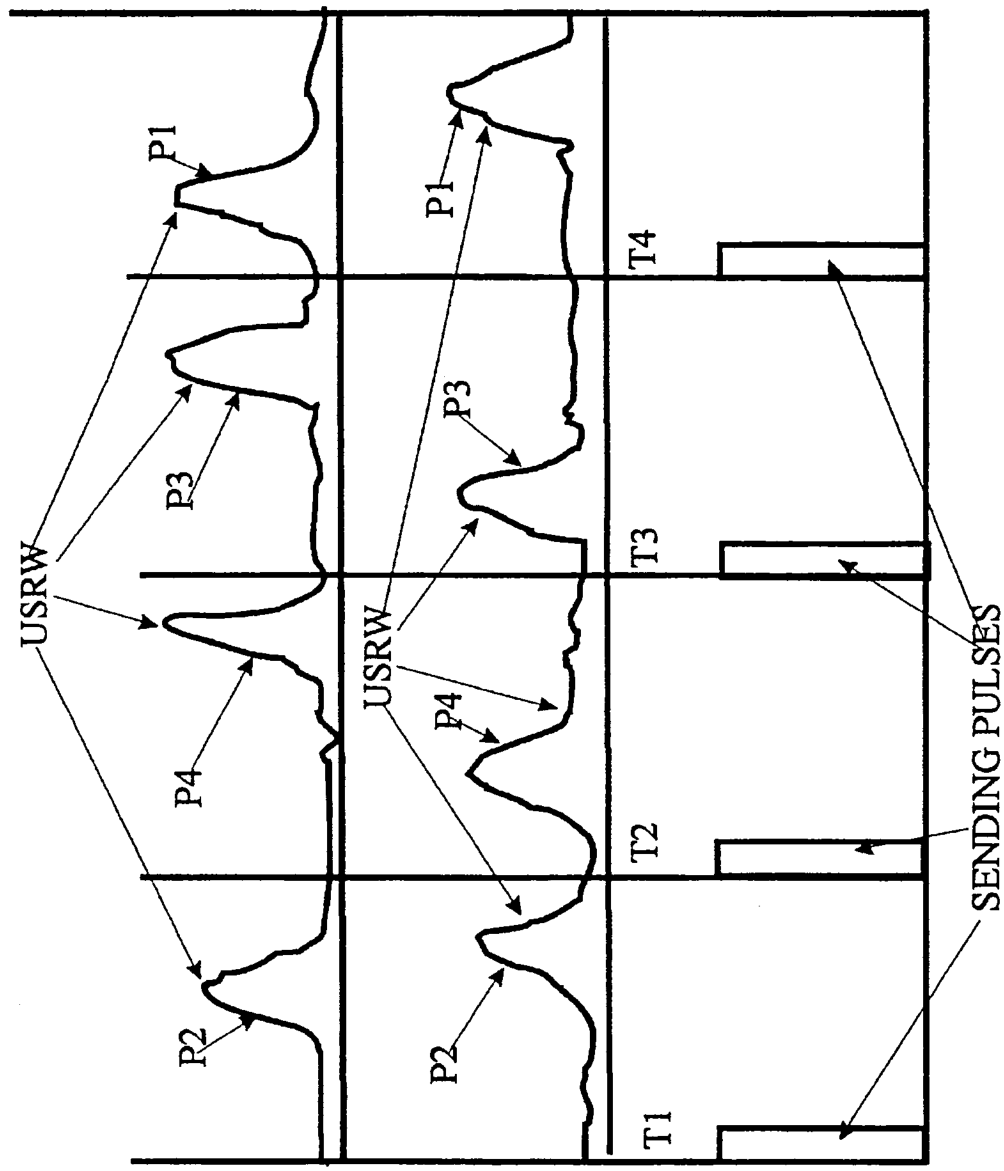



FIG. 4(a)

FIG. 4(b)

FIG. 4(c)

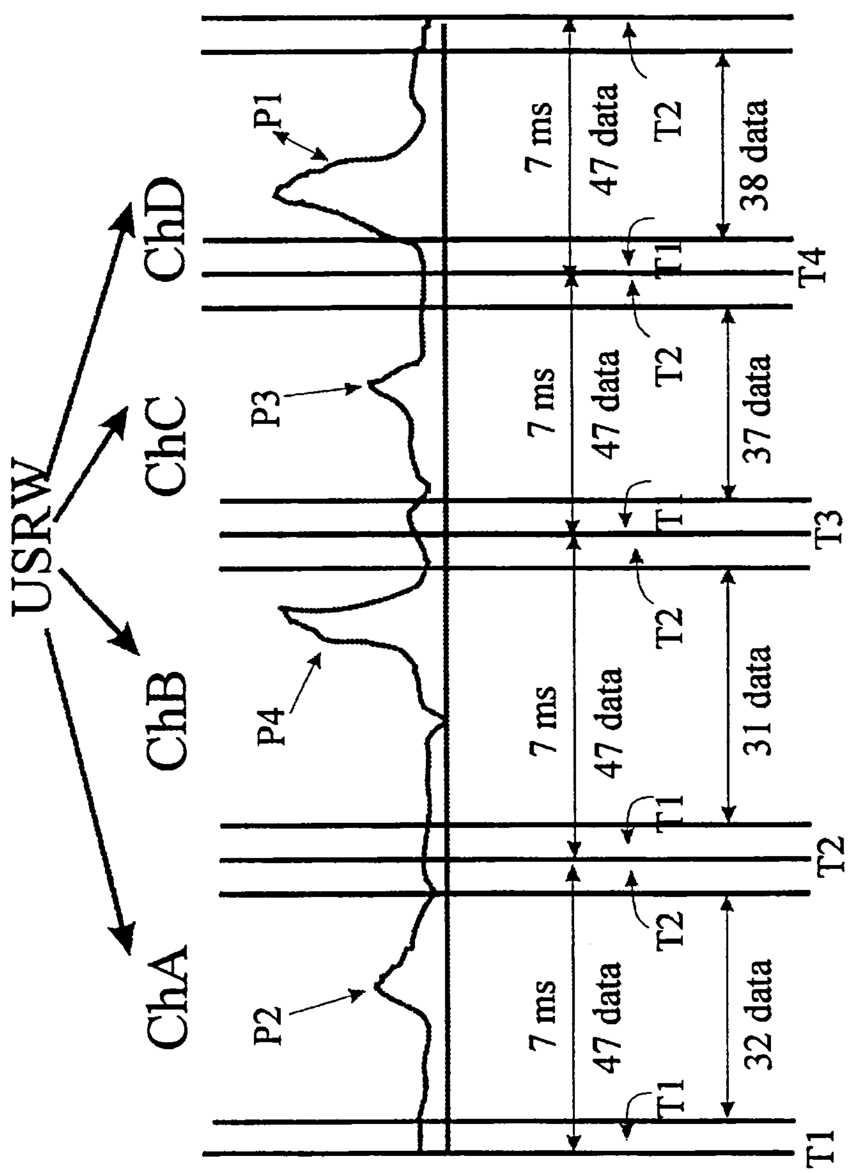

USRW
ChD
ChC
ChB
ChA
P1
P3
P4
P2
7 ms
7 ms
7 ms
7 ms
47 data
47 data
47 data
47 data
T2
T1
T2
T1
T2
T1
T2
T1
38 data
37 data
31 data
32 data
T4
T3
T2
T1

*FIG. 5*

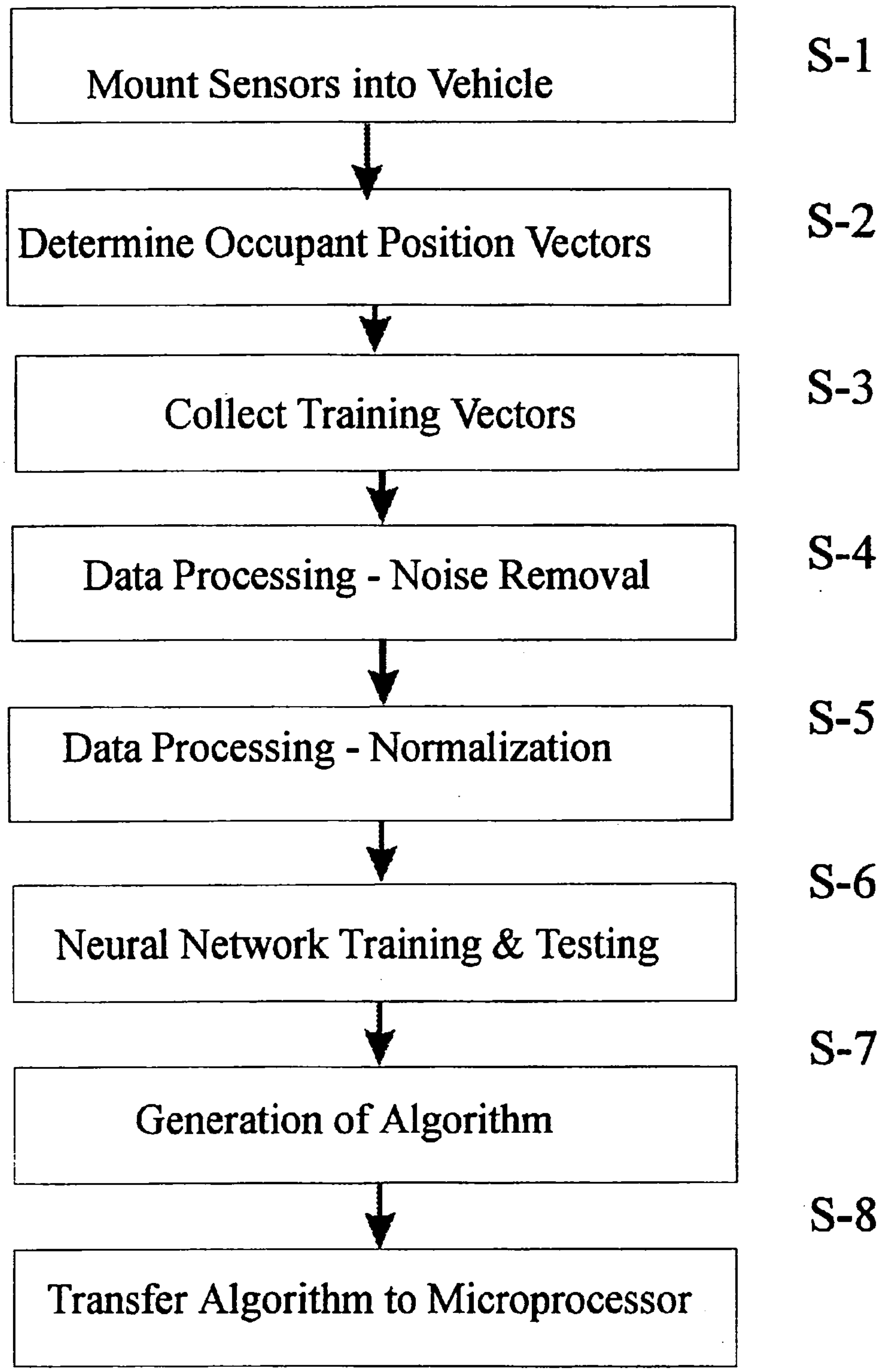
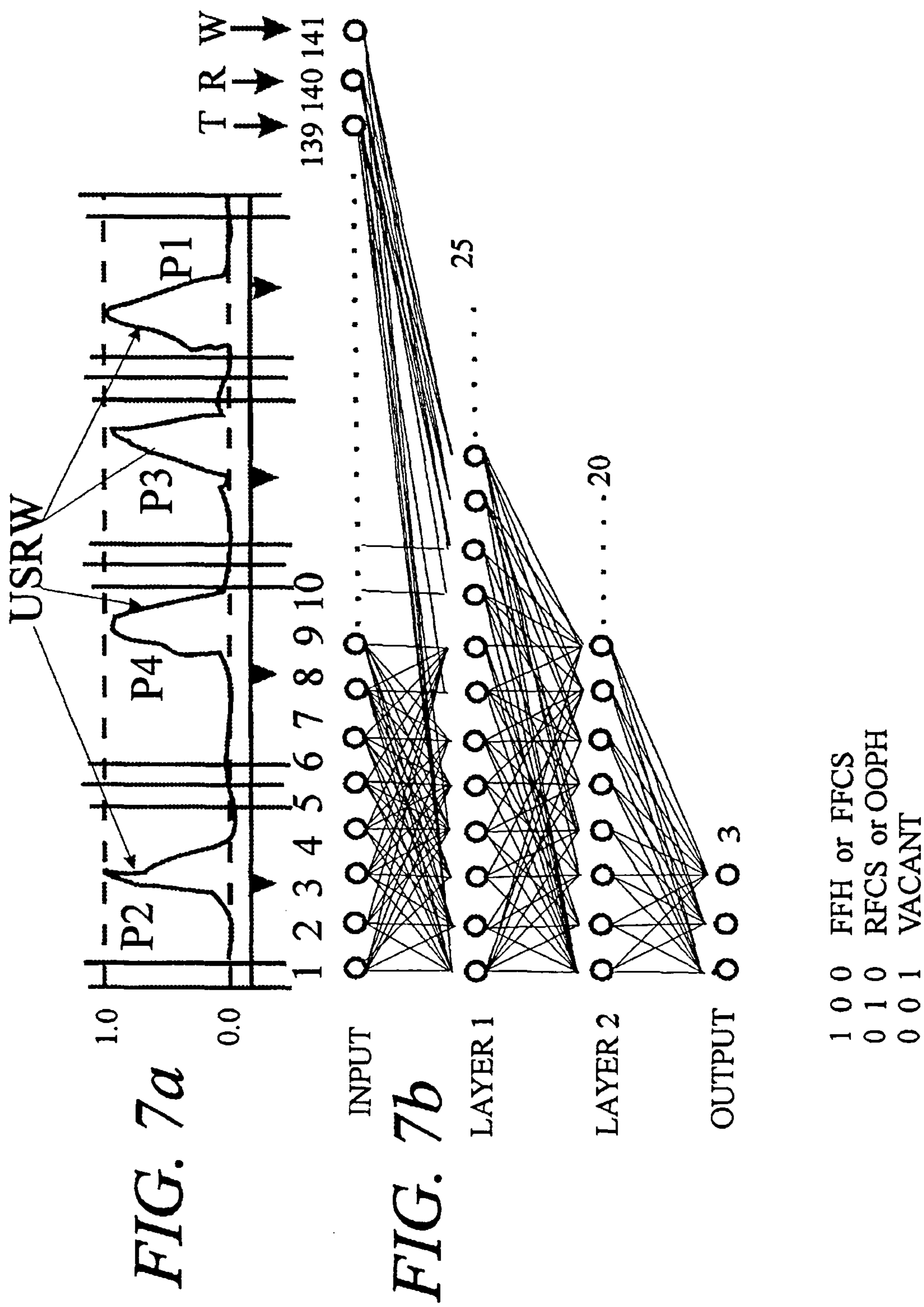

Mount Sensors into Vehicle
S-1
Determine Occupant Position Vectors
S-2
Collect Training Vectors
S-3
Data Processing - Noise Removal
S-4
Data Processing - Normalization
S-5
Neural Network Training & Testing
S-6
Generation of Algorithm
S-7
Transfer Algorithm to Microprocessor
S-8

*FIG. 6*



1.0
0.0
P1
P2
P3
P4
USRW
T
R
W
139 140 141
1 2 3 4 5 6 7 8 9 10
25
20
3
INPUT
LAYER 1
LAYER 2
OUTPUT
1 0 0 FFH or FFCS
0 1 0 RFCS or OOPH
0 0 1 VACANT


FIG. 7a

FIG. 7b

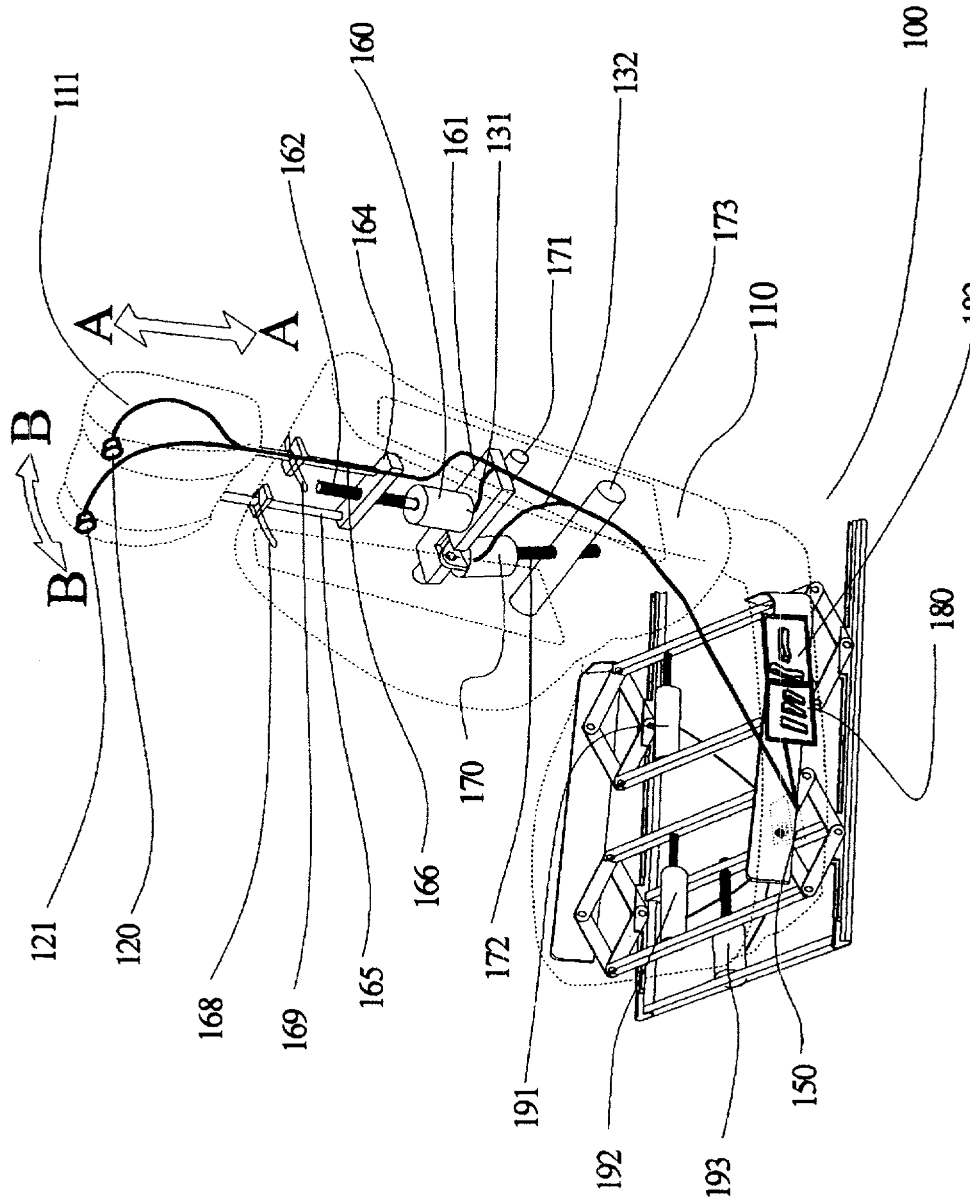

111
162
164
160
161
131
171
132
173
110
100
182
A
A
B
B
121
120
168
169
165
166
170
172
191
192
193
150
180

FIG. 8

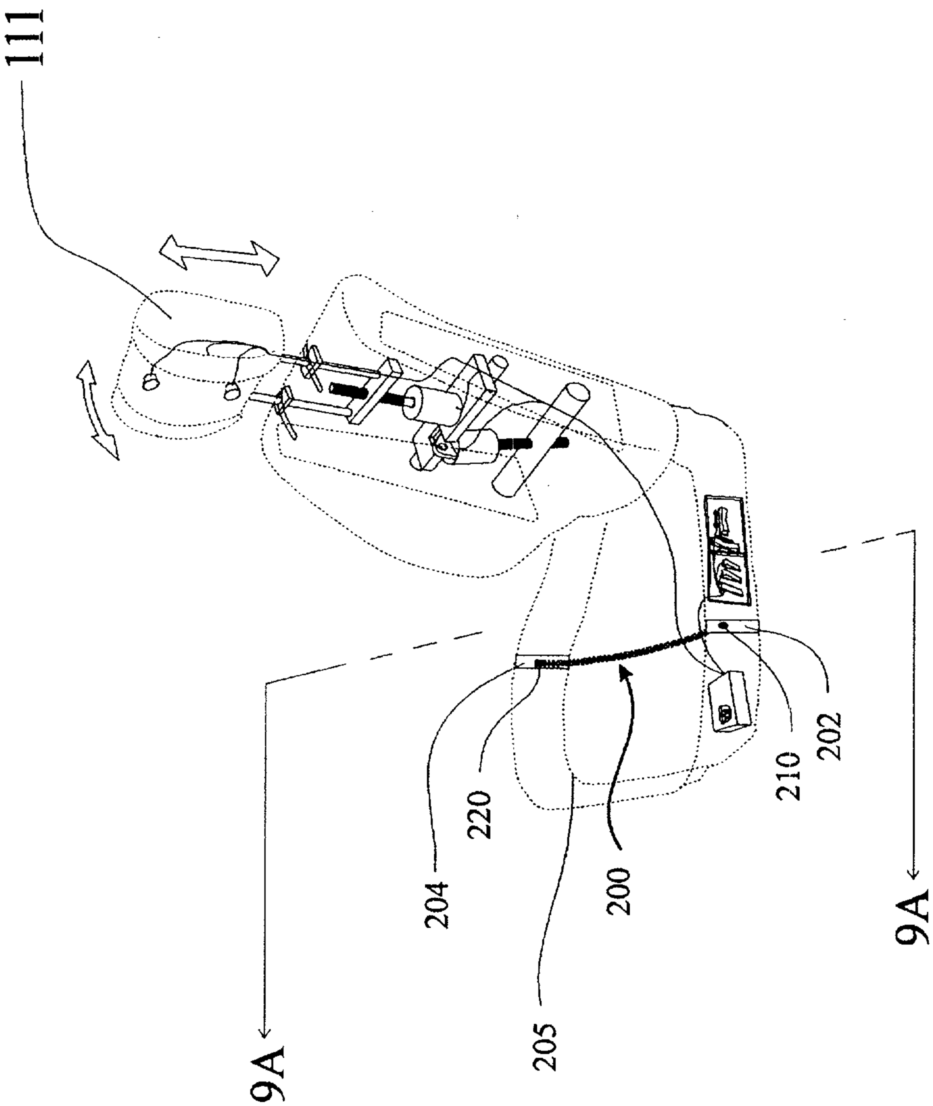



FIG. 9

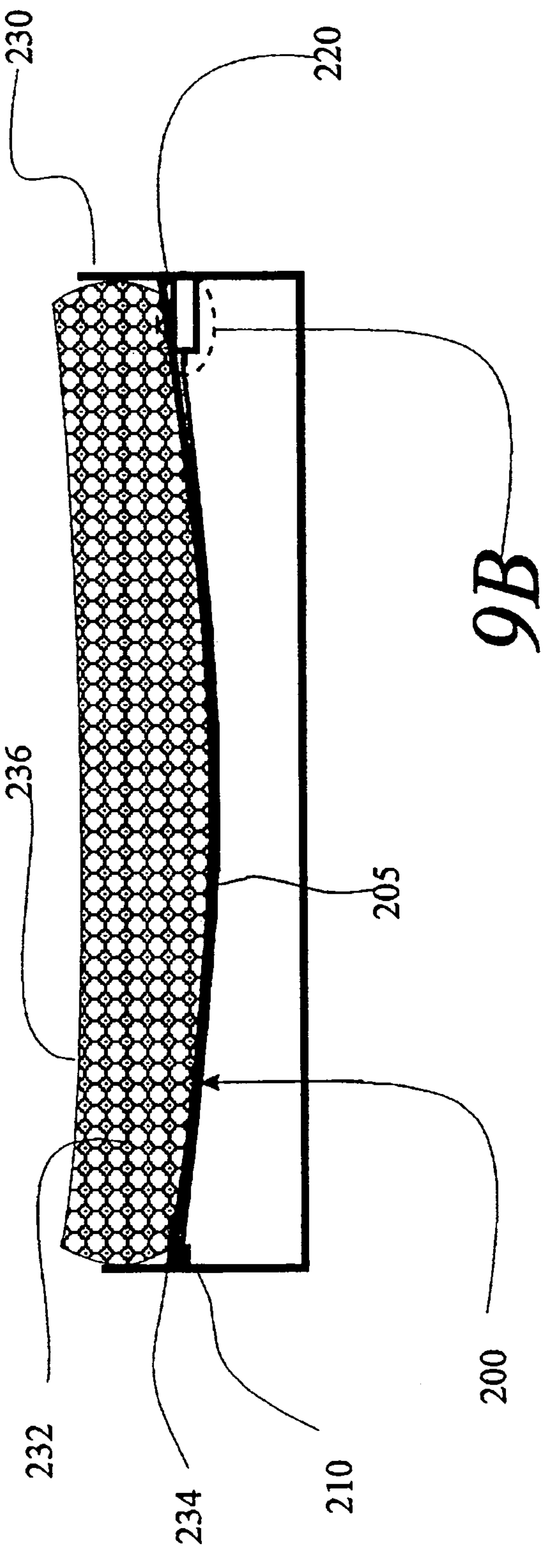



FIG. 9A

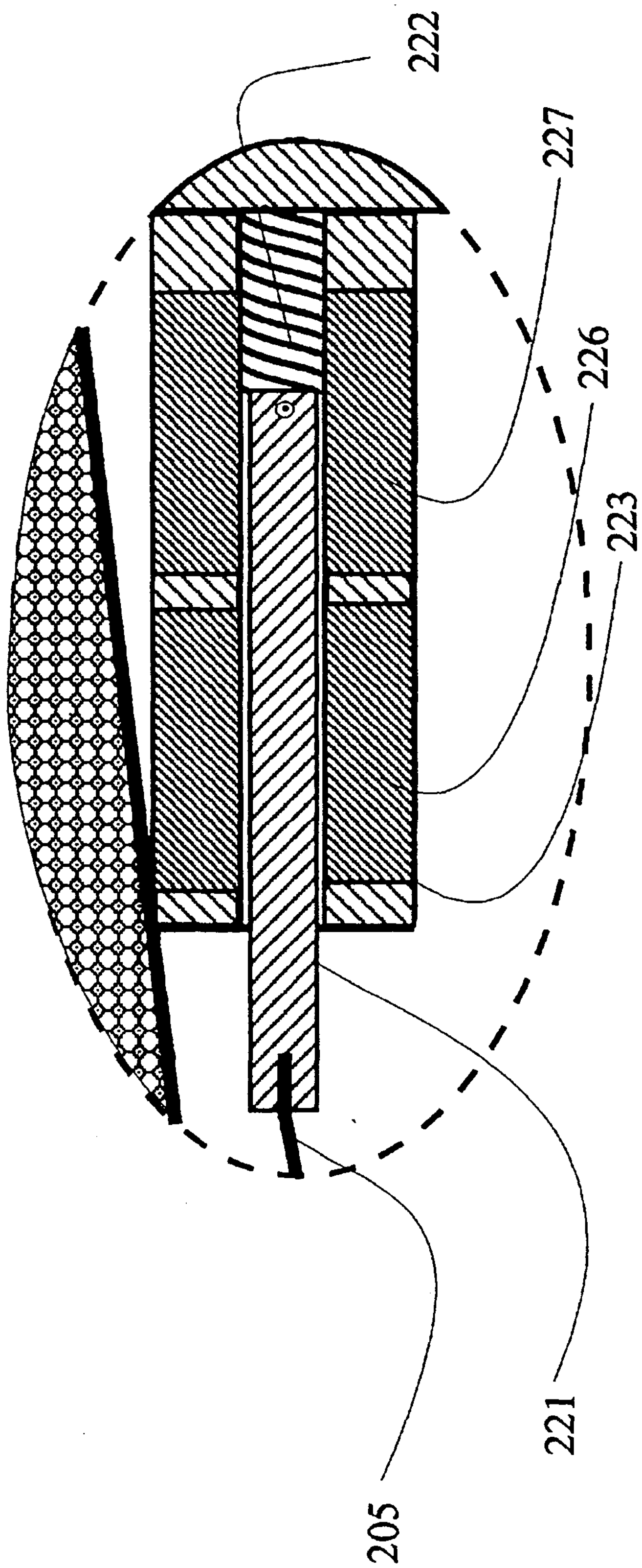



FIG. 9B

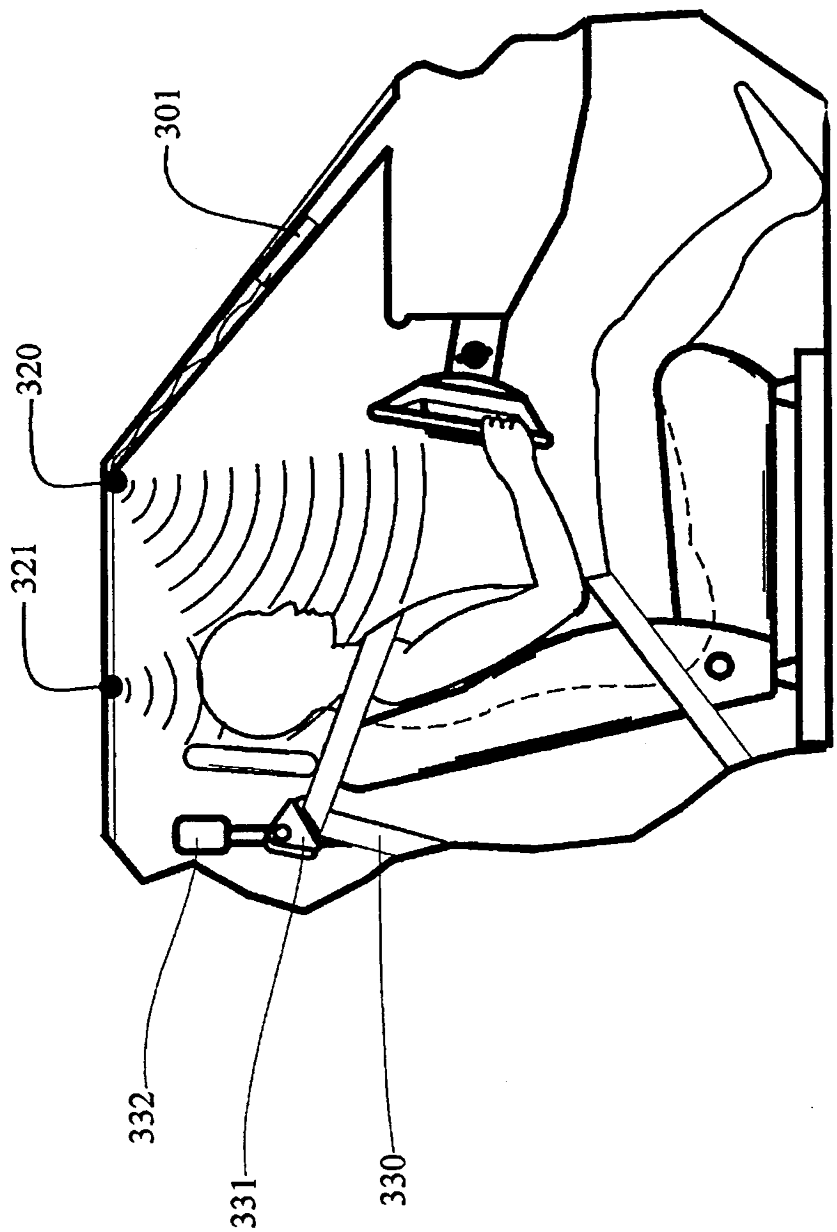



FIG. 10

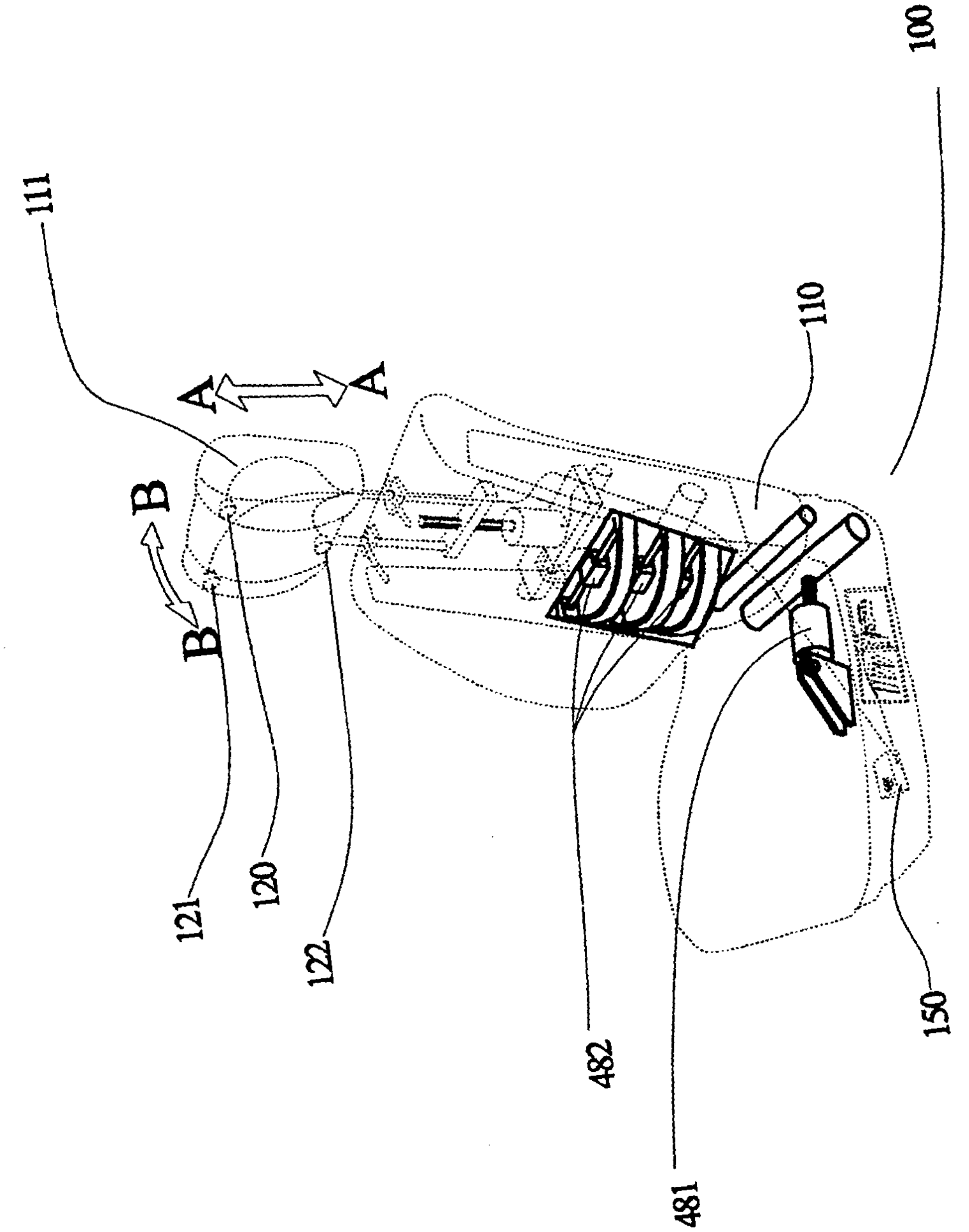



FIG. 11

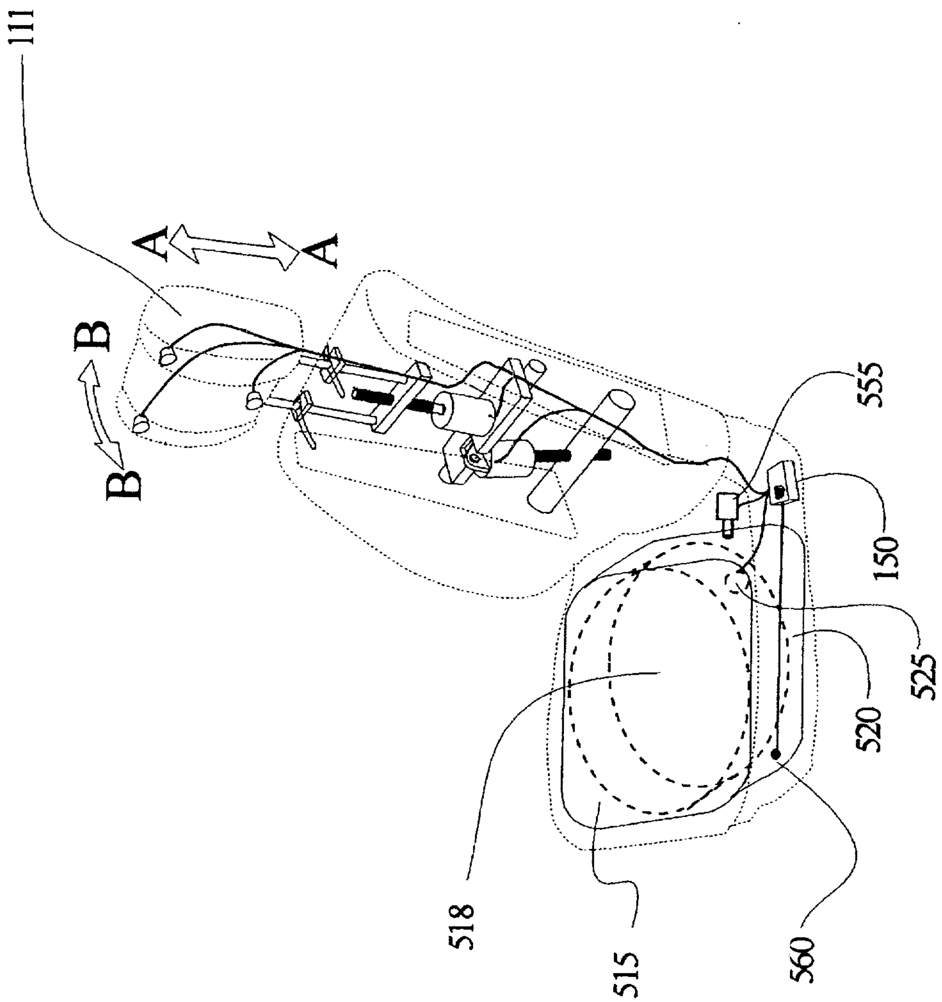



FIG. 12

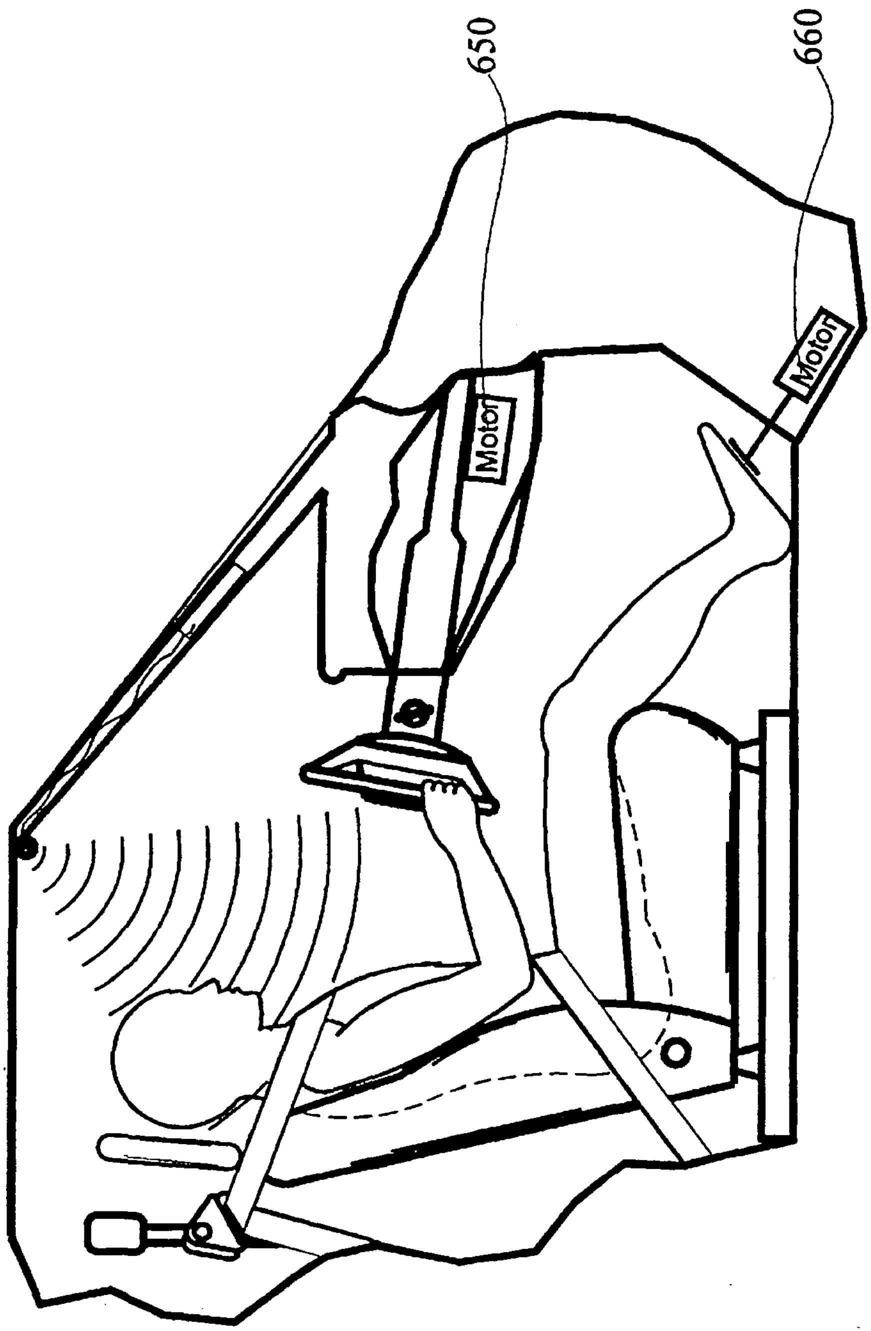



FIG. 13

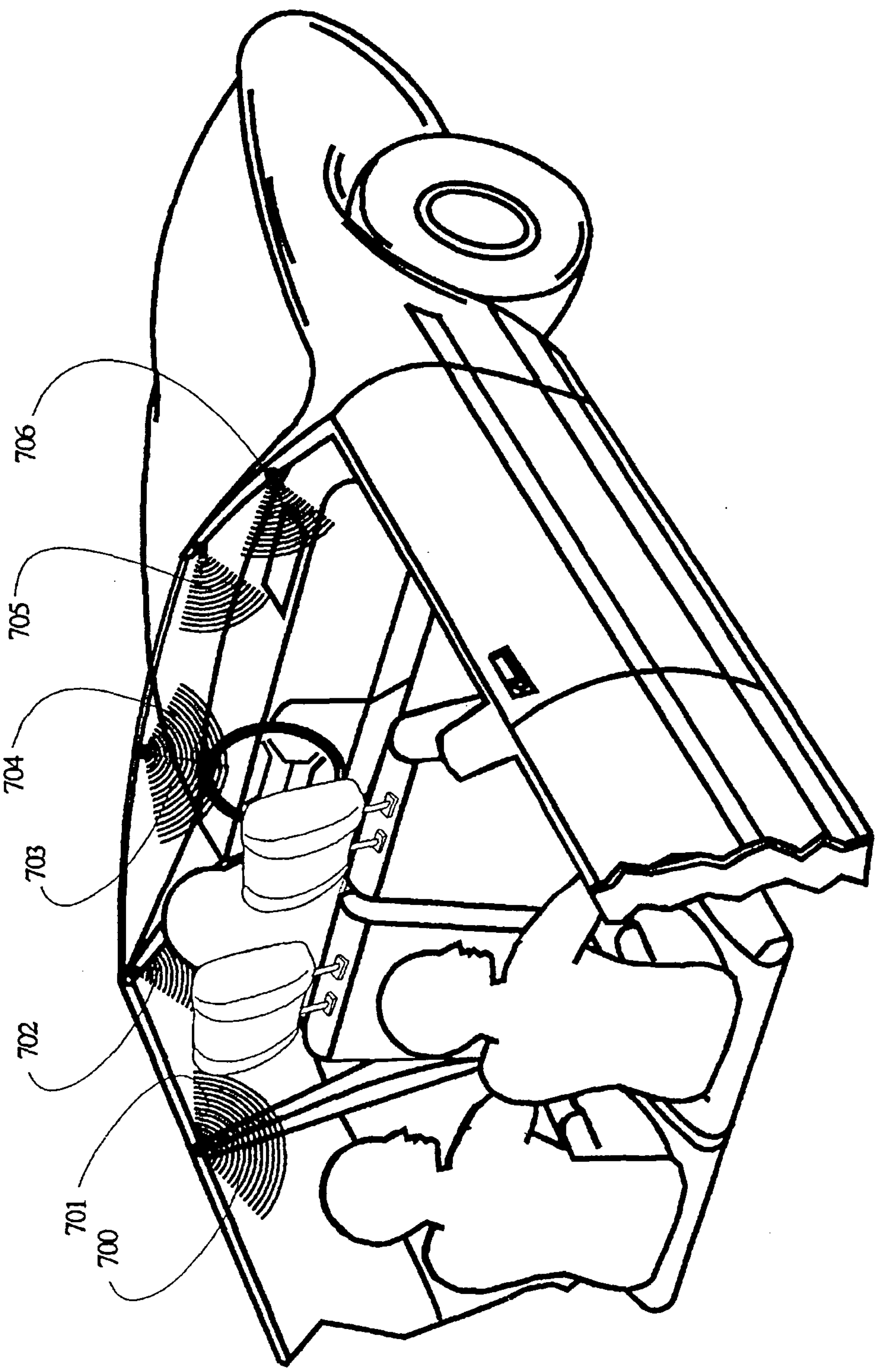



FIG. 14

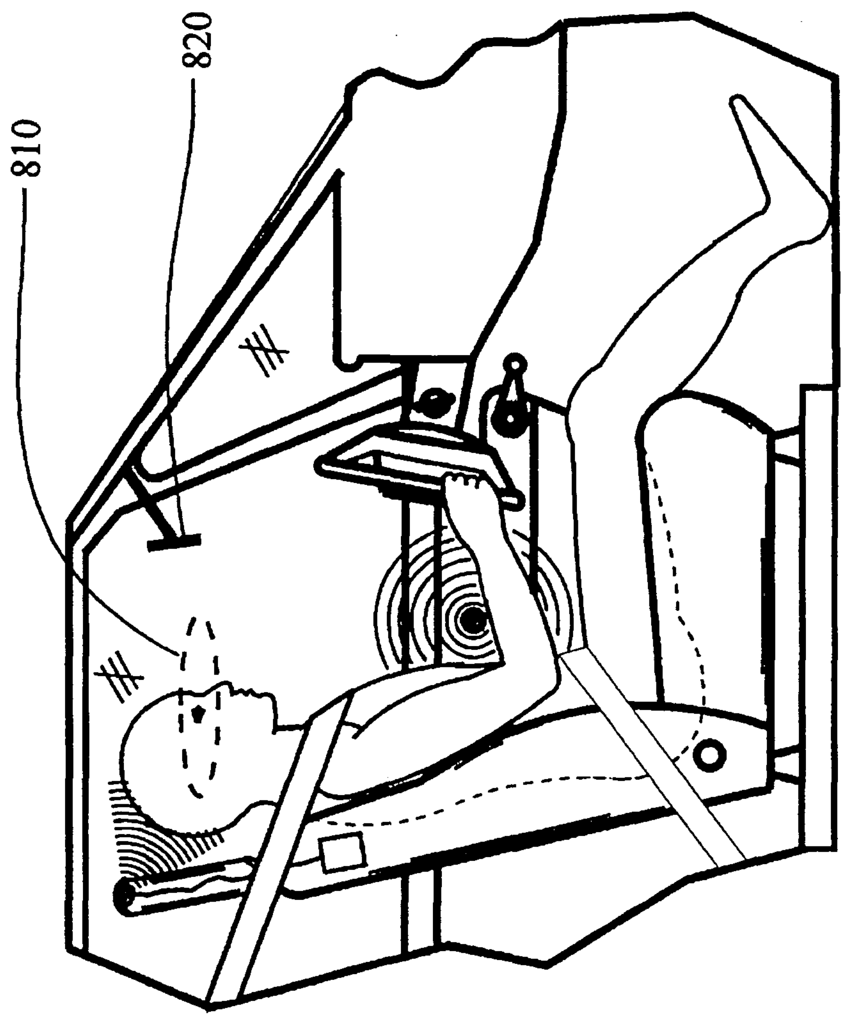



FIG. 15

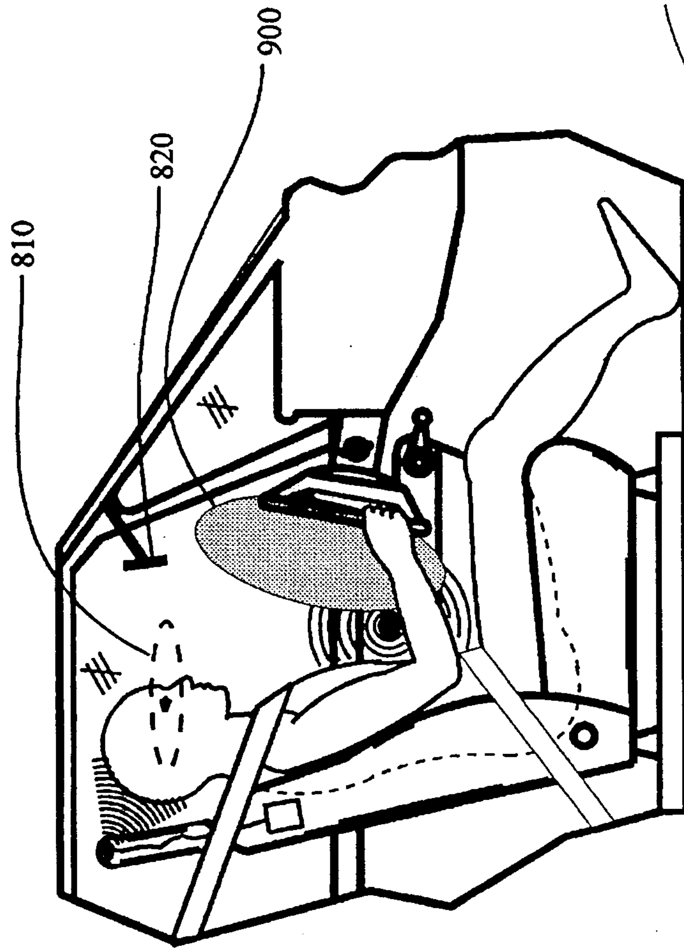



FIG. 16

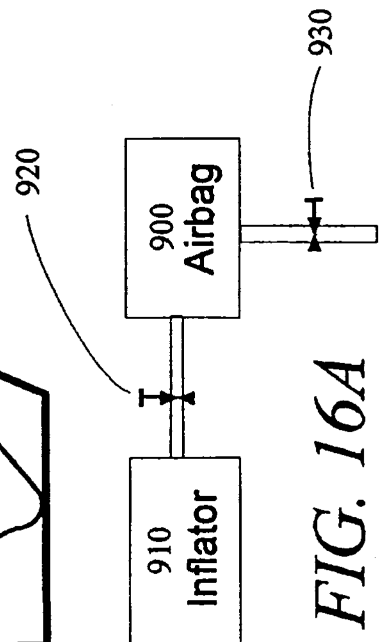



FIG. 16A

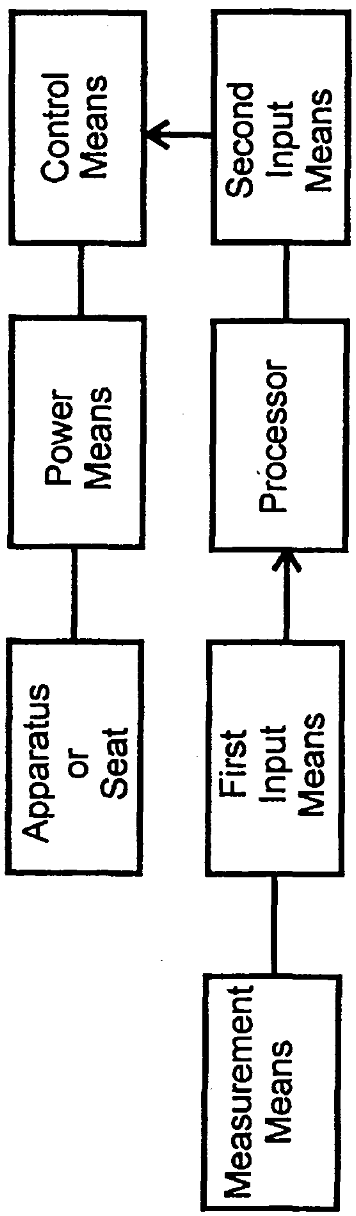



FIG. 17A

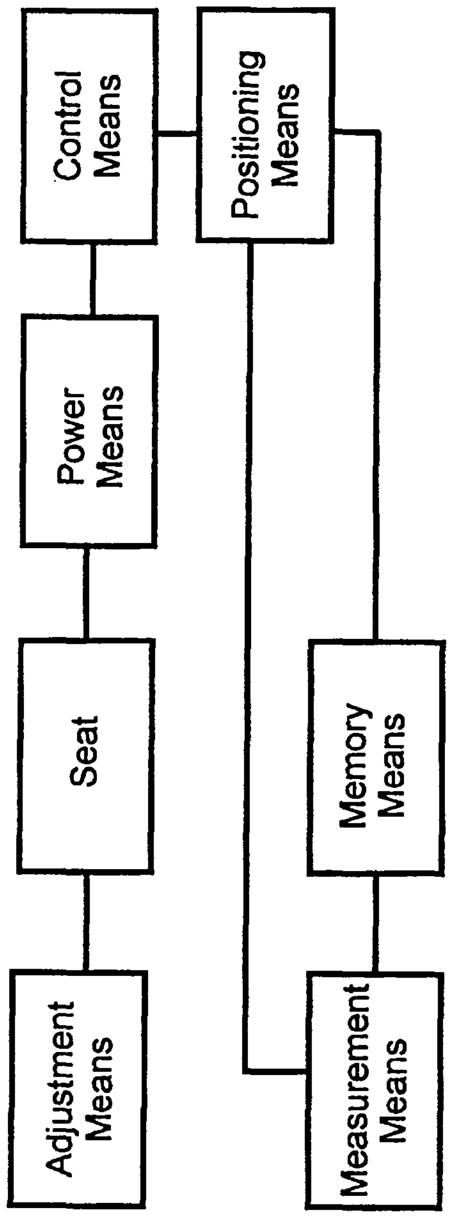



FIG. 17B

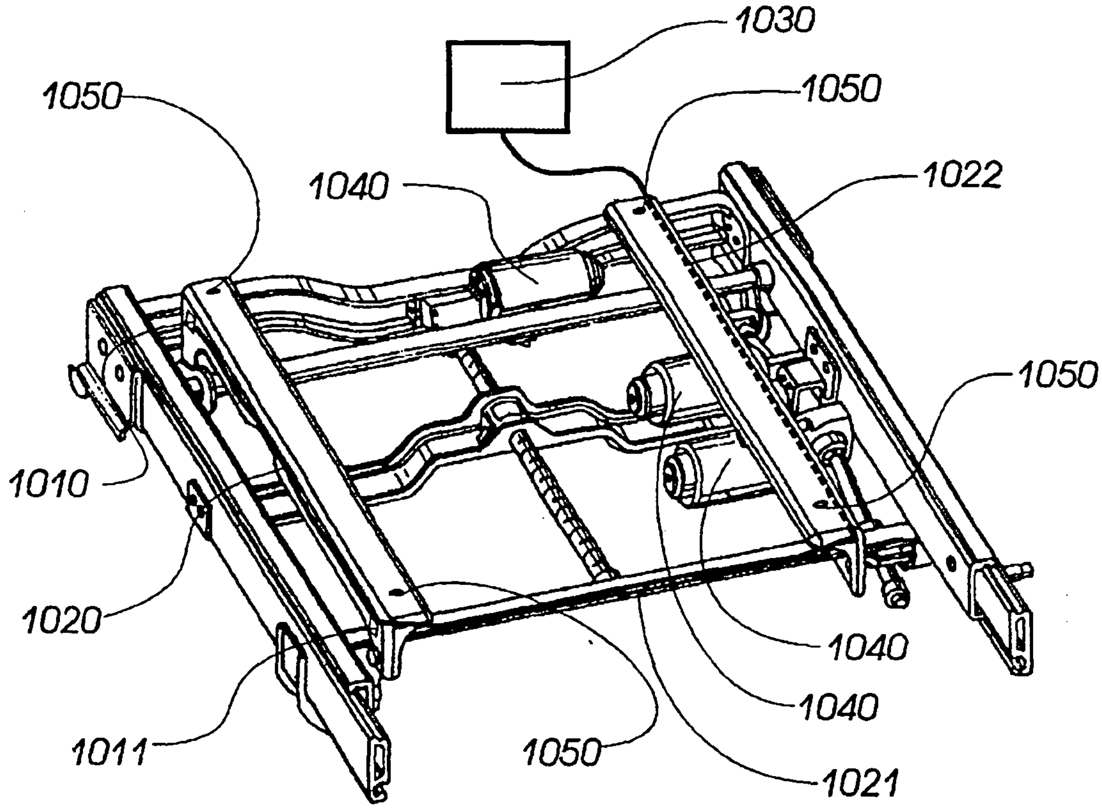

1030
1050
1050
1040
1022
1050
1010
1020
1040
1040
1011
1050
1021

Fig. 18

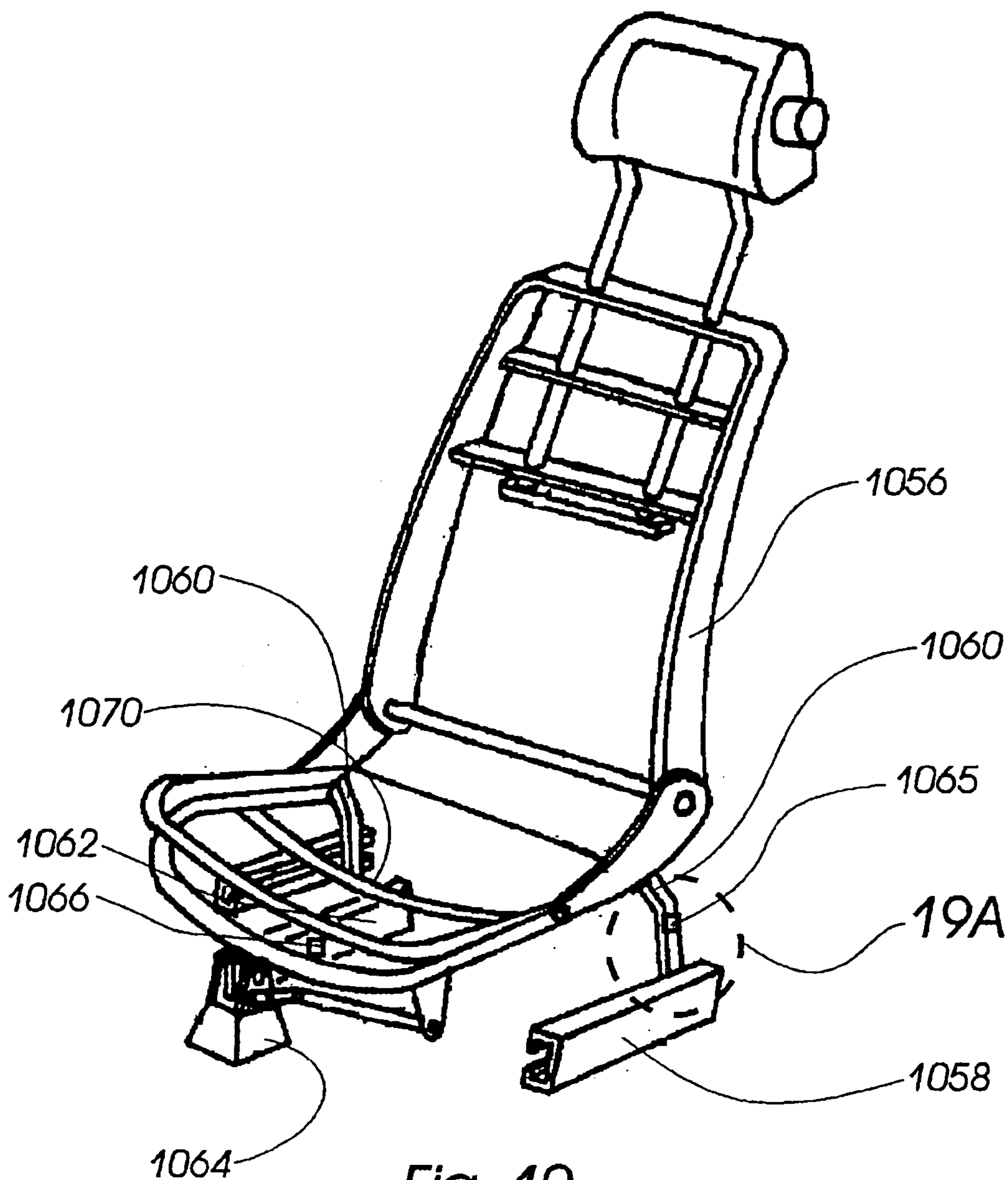



Fig. 19

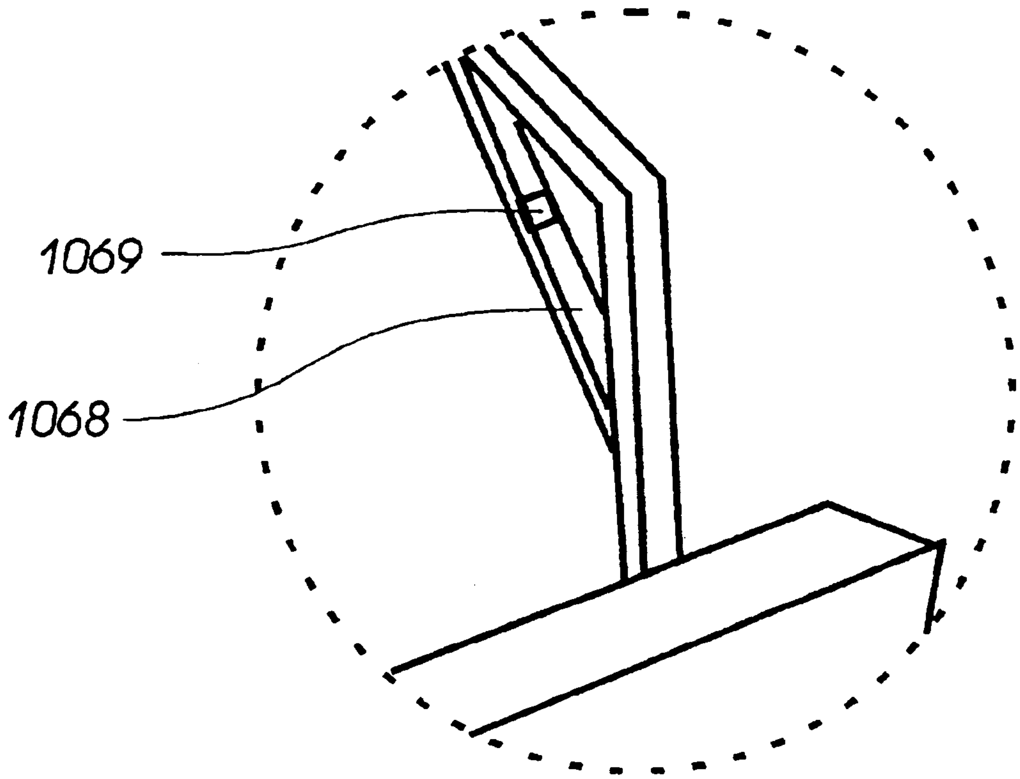



Fig. 19A

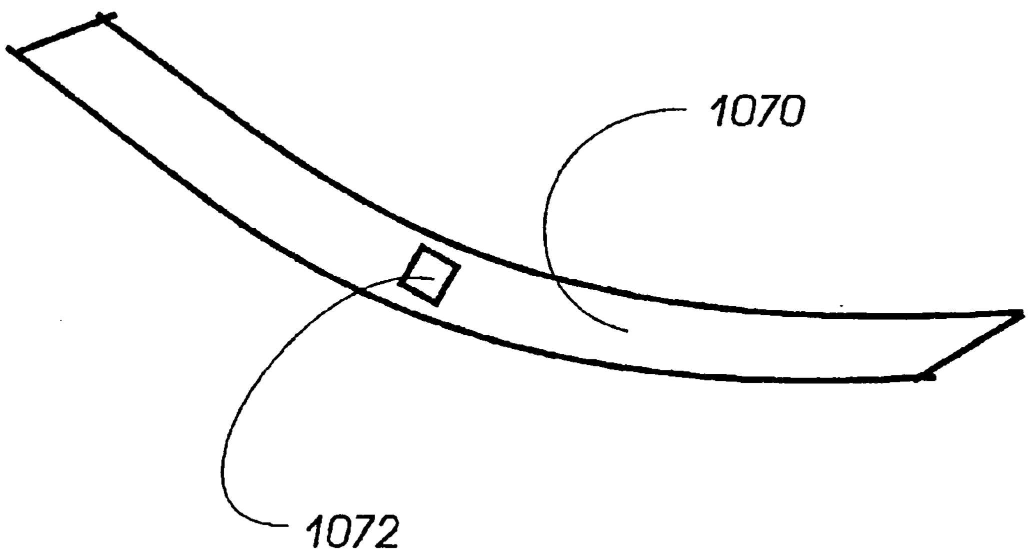



Fig. 19B

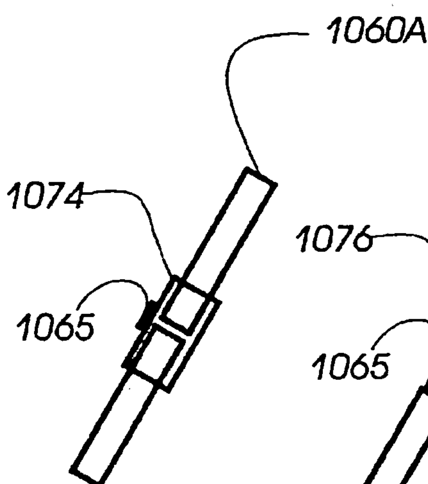



Fig. 20A

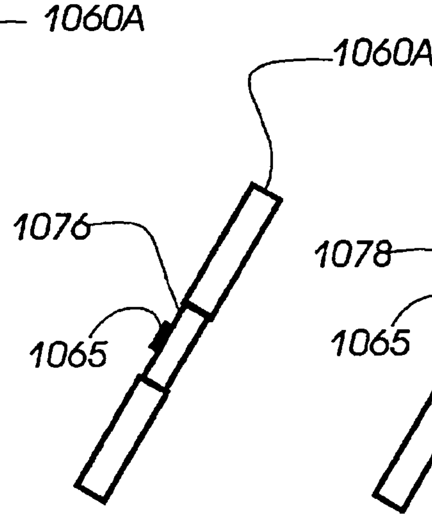



Fig. 20B

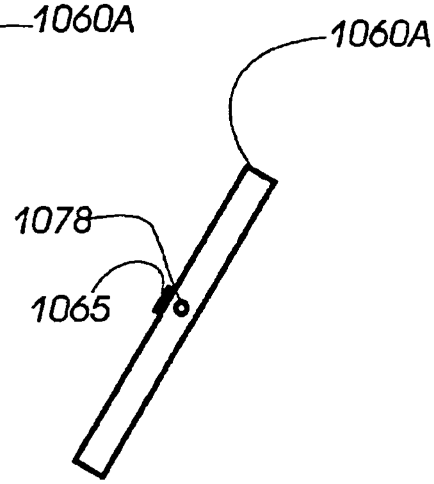



Fig. 20C

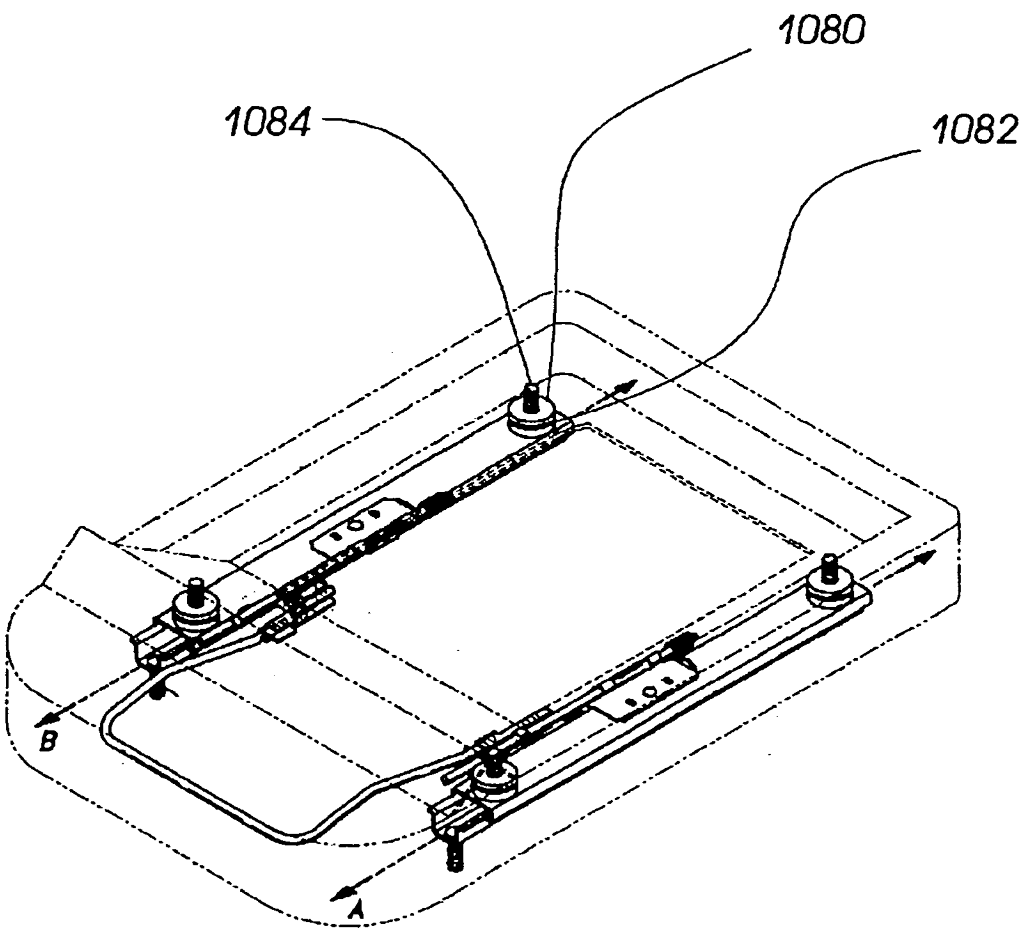



Fig. 21

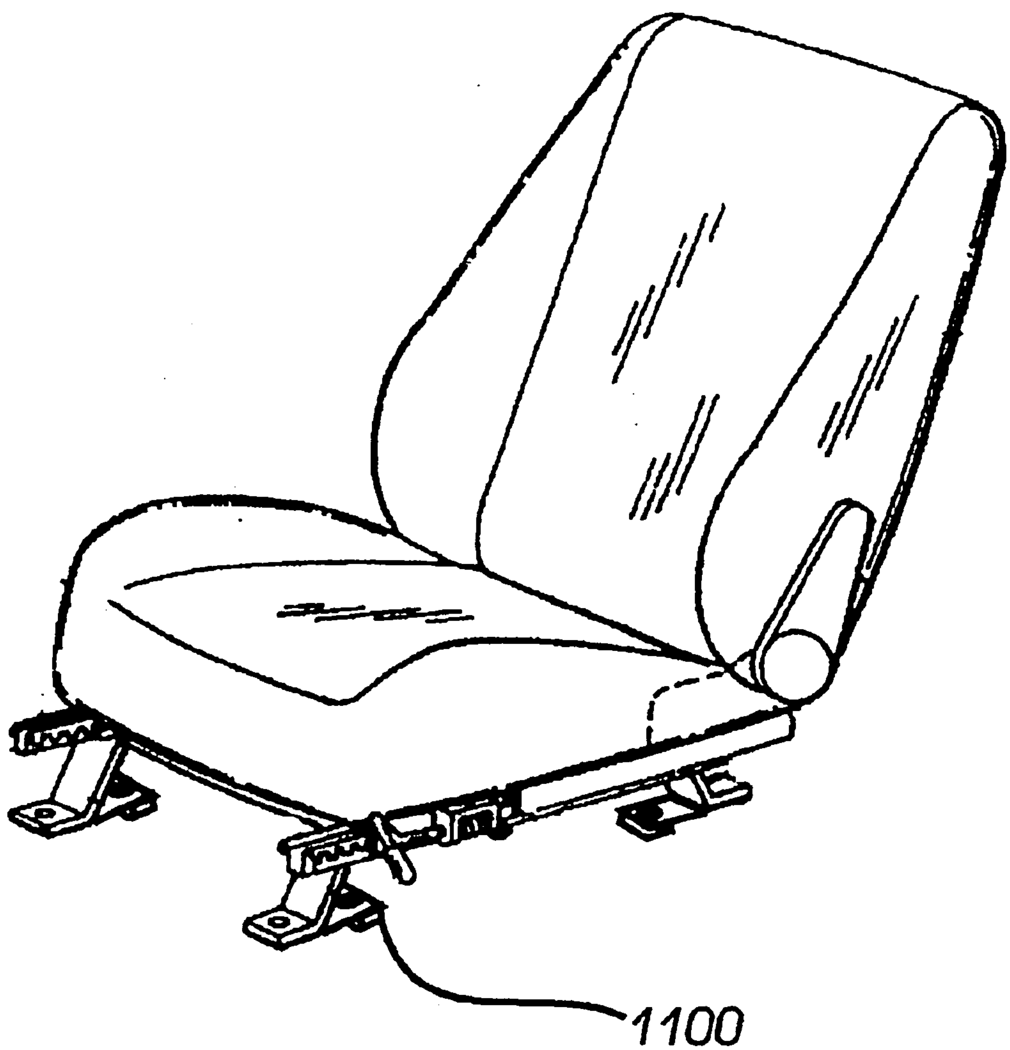



Fig. 22

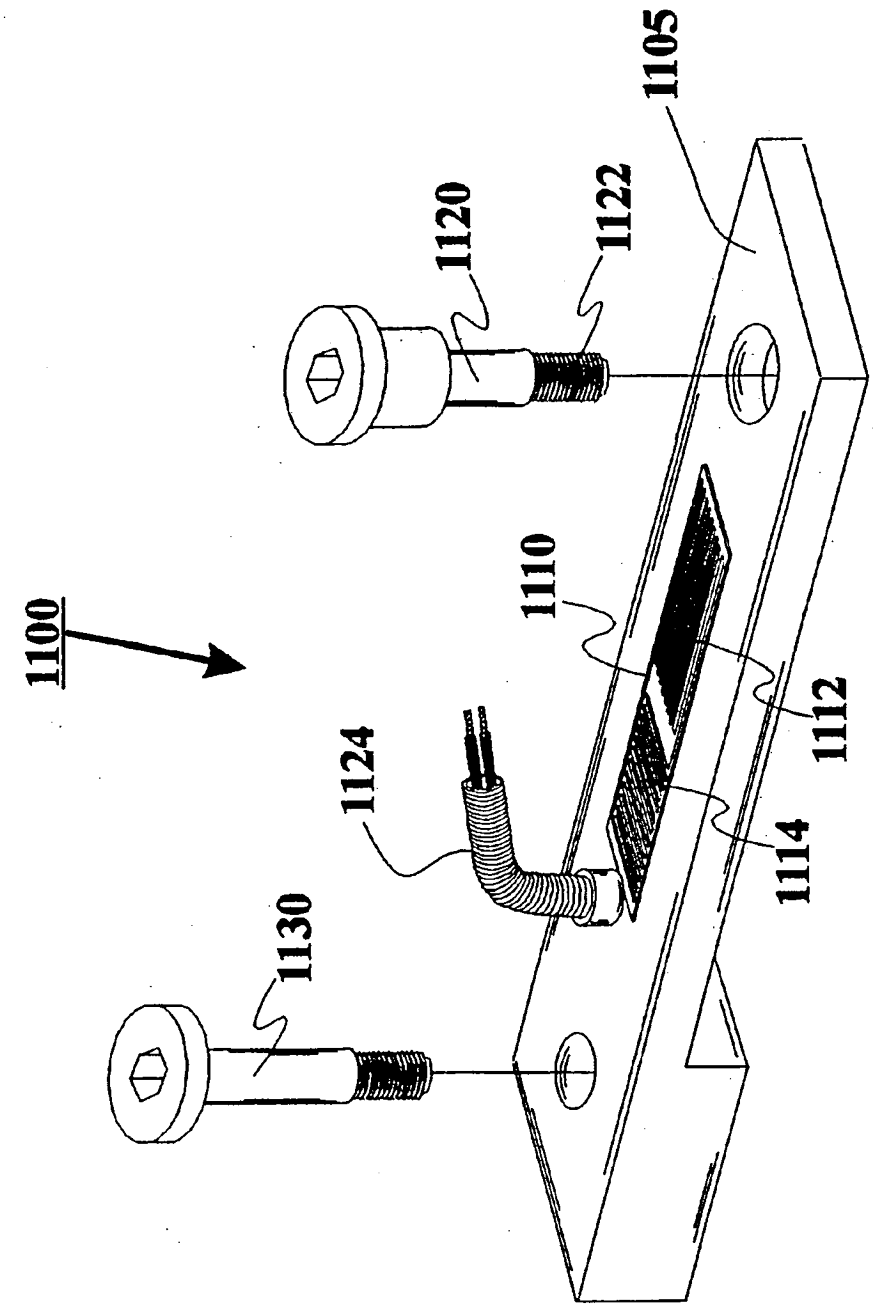



*FIG. 22A*

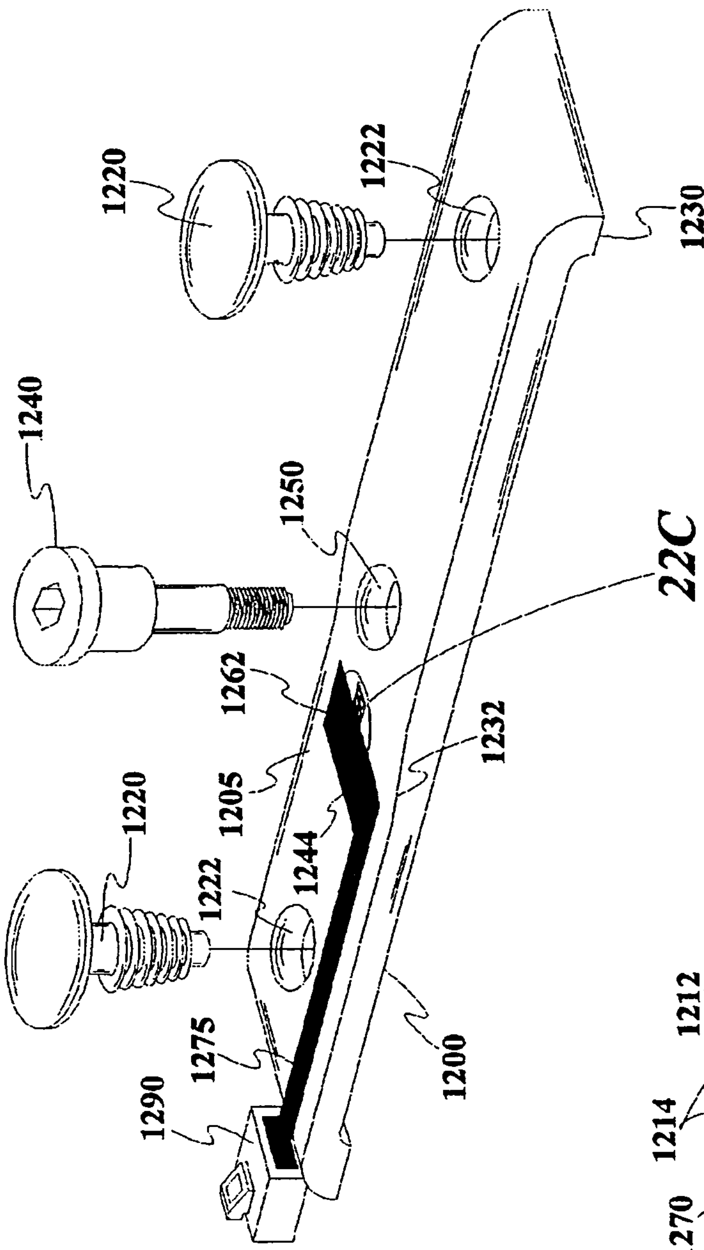



FIG. 22B

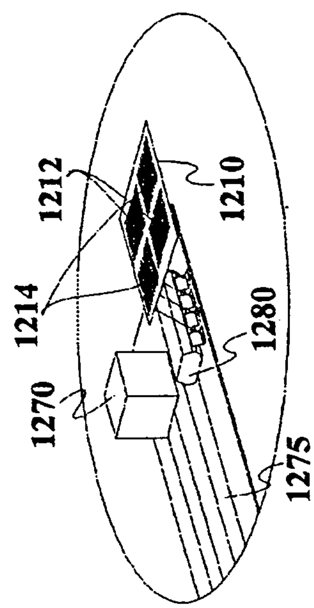



FIG. 22C

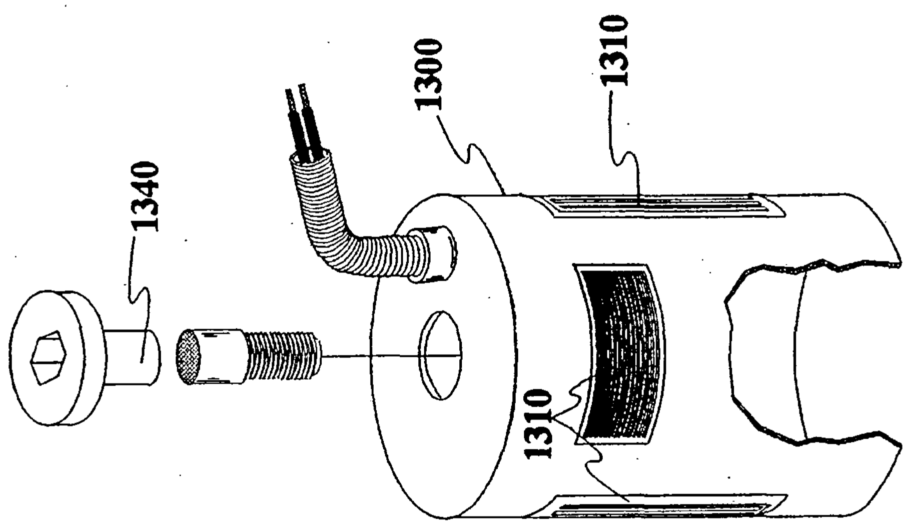



FIG. 22D

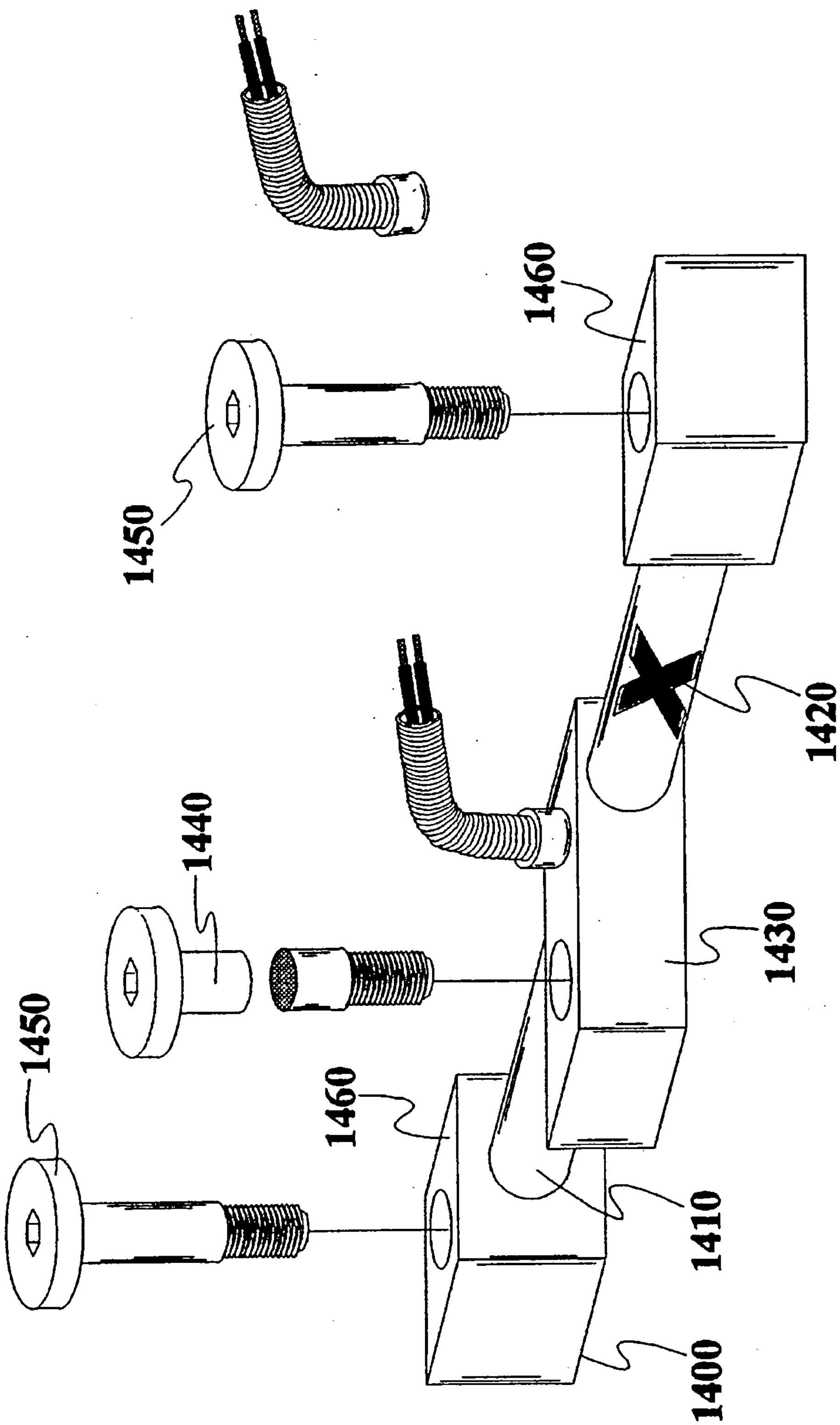



FIG. 22E

# APPARATUS AND METHOD FOR MEASURING WEIGHT OF AN OCCUPYING ITEM OF A SEAT

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 09/128,490 filed Aug. 4, 1998 now U.S. Pat. No. 6,078,854 which is both a continuation-in-part of U.S. patent application Ser. No. 08/474,783 filed Jun. 7, 1995, now U.S. Pat. No. 5,822,707, and a continuation-in-part of U.S. patent application Ser. No. 08/970,822 filed Nov. 14, 1997 now U.S. Pat. No. 6,081,757.

## FIELD OF THE INVENTION

The present invention relates to methods and apparatus for measuring the weight of an occupying item of a seat, in particular, a seat in an automotive vehicle.

The present invention also relates to apparatus and methods for adjusting a vehicle component, system or subsystem in which the occupancy of a seat, also referred to as the "seated state" herein, is evaluated using at least a weight measuring apparatus and the component, system or subsystem may then be adjusted based on the evaluated occupancy thereof. The vehicle component, system or subsystem, hereinafter referred to simply as a component, may be any adjustable component of the vehicle including, but not limited to, the bottom portion and backrest of the seat the rear view and side mirrors, the brake, clutch and accelerator pedals, the steering wheel, the steering column, a seat armrest, a cup holder, the mounting unit for a cellular telephone or another communications or computing device and the visors. Further, the component may be a system such an as airbag system, the deployment of which is controlled based on the seated-state of the seat. The component may also be an adjustable portion of a system the operation of which might be advantageously adjusted based on the seated-state of the seat, such as a device for regulating the inflation or deflation of an airbag that is associated with an airbag system.

The present invention also relates to apparatus and method for automatically adjusting a vehicle component to a selected or optimum position for an occupant of a seat based on at least two measured morphological characteristics of the occupant, one of which is the weight of the occupant. Other morphological characteristics include the height of the occupant, the length of the occupant's arms, the length of the occupant's legs, the occupant's head diameter and the inclination of the occupant's back relative to the seat bottom. Other, unlisted morphological characteristics are also envisioned for use in the invention.

## BACKGROUND OF THE INVENTION

Automobiles equipped with airbags are well known in the prior art. In such airbag systems, the car crash is sensed and the airbags rapidly inflated thereby insuring the safety of an occupation in a car crash. Many lives have now been saved by such airbag systems. However, depending on the seated state of an occupant, there are cases where his or her life cannot be saved even by present airbag systems. For example, when a passenger is seated on the front passenger seat in a position other than a forward facing, normal state, e.g., when the passenger is out of position and near the deployment door of the airbag, there will be cases when the occupant will be seriously injured or even killed by the deployment of the airbag.



Also, sometimes a child seat is placed on the passenger seat in a rear facing position and there are cases where a child sitting in such a seat has been seriously injured or killed by the deployment of the airbag.

Furthermore, in the case of a vacant seat, there is no need to deploy an airbag, and in such a case, deploying the airbag is undesirable due to a high replacement cost and possible release of toxic gases into the passenger compartment. Nevertheless, most airbag systems will deploy the airbag in a vehicle crash even if the seat is unoccupied.

For these reasons, there has been proposed a seated-state detecting unit such as disclosed in the following U.S. Patents and Patent applications, which are included herein by reference, assigned to the current assignee of the present application: Breed et al (U.S. Pat. No. 5.563,462); Breed et al (U.S. patent application Ser. No. 08/640,068 filed Apr. 30, 1996), Breed et al (U.S. Pat. No. 5,822,707: Breed et al (U.S. Pat. No. 5,694,320); Breed et al (U.S. Pat. No. 5,748.473); and Varga et al (U.S. patent application Ser. No. 08/798,029 filed Feb. 6, 1997). Typically, in some of these designs four sets of sensors are installed at four points in a vehicle passenger compartment for transmitting ultrasonic or electromagnetic waves toward the passenger or driver's seat and receiving the reflected waves. Using appropriate hardware and software, the approximate configuration of the occupancy of either the passenger or driver seat can be determined thereby identifying and categorizing the occupancy of the relevant seat.

However, in the aforementioned literature using ultrasonics, the pattern of reflected ultrasonic waves from an adult occupant who may be out of position is sometimes similar to the pattern of reflected waves from a rear facing child seat. Also, it is sometimes difficult to discriminate the wave pattern of a normally seated child with the seat in a rear facing position from an empty seat with the seat in a more forward position. In other cases, the reflected wave pattern from a thin slouching adult with raised knees can be similar to that from a rear facing child seat. In still other cases, the reflected pattern from a passenger seat which is in a forward position can be similar to the reflected wave pattern from a seat containing a forward facing child seat or a child sitting on the passenger seat. In each of these cases, the prior art ultrasonic systems can suppress the deployment of an airbag when deployment is desired or, alternately, can enable deployment when deployment is not desired.

If the discrimination between these cases can be improved, then the reliability of the seated-state detecting unit can be improved and more people saved from death or serious injury. In addition, the unnecessary deployment of an airbag can be prevented.

With respect to the adjustment of a vehicular seat, the adjustment of an automobile seat occupied by a driver of the vehicle is now accomplished by the use of either electrical switches and motors or by mechanical levers. As a result, the driver's seat is rarely placed at the proper driving position which is defined as the seat location which places the eyes of the driver in the so-called "eye ellipse" and permits him or her to comfortably reach the pedals and steering wheel. The "eye ellipse" is the optimum eye position relative to the windshield and rear view mirror of the vehicle.

The eye ellipse, which is actually an ellipsoid, is rarely achieved by the actions of the driver for a variety of reasons. One specific reason is the poor design of most seat adjustment systems particularly the so-called "4-way-seat". It is known that there are three degrees of freedom of a seat bottom, namely vertical, longitudinal, and rotation about the

lateral or pitch axis. The 4-way-seat provides four motions to control the seat: (1) raising or lowering the front of the seat, (2) raising or lowering the back of the seat, (3) raising or lowering the entire seat, (4) moving the seat fore and aft. Such a seat adjustment system causes confusion since there are four control motions for three degrees of freedom. As a result, vehicle occupants are easily frustrated by such events as when the control to raise the seat is exercised, the seat not only is raised but is also rotated. Occupants thus find it difficult to place the seat in the optimum location using this system and frequently give up trying leaving the seat in an improper driving position.

Many vehicles today are equipped with a lumbar support system that is never used by most occupants. One reason is that the lumbar support cannot be preset since the shape of the lumbar for different occupants differs significantly, i.e., a tall person has significantly different lumbar support requirements than a short person. Without knowledge of the size of the occupant, the lumbar support cannot be automatically adjusted.

As discussed in the above referenced '320 patent, in approximately 95% of the cases where an occupant suffers a whiplash injury, the headrest is not properly located to protect him or her in a rear impact collision. Also, the stiffness and damping characteristics of a seat are fixed and no attempt is made in any production vehicle to adjust the stiffness and damping of the seat in relation to either the size or weight of an occupant, or to the environmental conditions such as road roughness. All of these adjustments, if they are to be done automatically, require knowledge of the morphology of the seat occupant.

Systems are now being used to attempt to identify the vehicle occupant based on a coded key or other object carried by the occupant. This requires special sensors within the vehicle to recognize the coded object. Also, the system only works if the coded object is used by the particular person for whom the vehicle was programmed. If the vehicle is used by a son or daughter, for example, who use their mother's key then the wrong seat adjustments are made. Also, these systems preserve the choice of seat position without any regard for the correctness of the seat position. With the problems associated with the 4-way seats, it is unlikely that the occupant ever properly adjusts the seat. Therefore, the error will be repeated every time the occupant uses the vehicle.

Moreover, these coded systems are a crude attempt to identify the occupant. An improvement can be made if the morphological characteristics of the occupant can be measured as described below. Such measurements can be made of the height and weight, for example, and used not only to adjust a vehicular component to a proper position but also to remember that position, as fine tuned by the occupant, for re-positioning the component the next time the occupant occupies the seat. For the purposes herein, a morphological characteristic will mean any measurable property of a human such as height, weight, leg or arm length, head diameter etc.

As discussed more fully below, in a preferred implementation, once at least one and preferably two of the morphological characteristics of a driver are determined, e.g., by measuring his or her height and weight, the component such as the seat can be adjusted and other features or components can be incorporated into the system including, for example, the automatic adjustment of the rear view and/or side mirrors based on seat position and occupant height. In addition, a determination of an out-of-position occupant can be made and based thereon, airbag deployment suppressed if the occupant is more likely to be injured by the airbag than by the accident without the protection of the airbag. Furthermore, the characteristics of the airbag including the amount of gas produced by the inflator and the size of the airbag exit orifices can be adjusted to provide better protection for small lightweight occupants as well as large, heavy people. Even the direction of the airbag deployment can, in some cases, be controlled.

Still other features or components can now be adjusted based on the measured occupant morphology as well as the fact that the occupant can now be identified. Some of these features or components include the adjustment of seat armrest, cup holder, steering wheel (angle and telescoping), pedals, phone location and for that matter the adjustment of all things in the vehicle which a person must reach or interact with. Some items that depend on personal preferences can also be automatically adjusted including the radio station, temperature, ride and others.

Heretofore, various methods have been proposed for measuring the weight of an occupying item of a vehicular seat. The methods include pads, sheets or films that have placed in the seat cushion which attempt to measure the pressure distribution of the occupying item. Prior to its first disclosure in U.S. Pat. No. 5,822,707 cross-referenced above, systems for measuring occupant weight based on the strain in the seat structure had not been considered. Prior art weight measurement systems have been notoriously inaccurate. Thus, a more accurate weight measuring system is desirable. The strain measurement systems described herein, substantially eliminate the inaccuracy problems of prior art systems and permit an accurate determination of the weight of the occupying item of the vehicle seat. Additionally, as disclosed herein, in many cases, sufficient information can be obtained for the control of a vehicle component without the necessity of determining the entire weight of the occupant. For example, the force that the occupant exerts on one of the three support members may be sufficient.

Most, if not all, of the problems discussed above are difficult to solve or unsolvable using conventional technology.

## OBJECTS OF THE INVENTION

Accordingly, it is a principal object of the present invention to provide new and improved apparatus and methods for measuring the weight of an occupying item on a vehicle seat which apparatus and methods may be integrated into vehicular component adjustment apparatus and methods which evaluate the occupancy of the seat and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat.

It is another object of the present invention to provide new and improved adjustment apparatus and methods that evaluate the occupancy of the seat and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat and on a measurement of the occupant's weight or a measurement of a force exerted by the occupant on the seat.

It is another object of the present invention to provide new and improved adjustment apparatus and methods that evaluate the occupancy of the seat by a combination of ultrasonic sensors and additional sensors and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat.

It is another object of the present invention to provide new and improved adjustment apparatus and methods that reliably discriminate between a normally seated passenger and a forward facing child seat, between an abnormally seated passenger and a rear facing child seat, and whether or not the seat is empty and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based thereon.

It is another object of the present invention to provide an improved weight measurement system and thereby improve the accuracy of another apparatus or system which utilizes measured weight as input, e.g., a component adjustment apparatus.

It is another object of the present invention to provide new and improved adjustment apparatus and methods that evaluate the occupancy of the seat without the problems mentioned above.

Additional objects and advantages of this invention include:

1. To provide a system for passively and automatically adjusting the position of a vehicle component to a near optimum location based on the size of an occupant.

2. To provide a system for recognizing a particular occupant of a vehicle and thereafter adjusting various components of the vehicle in accordance with the preferences of the recognized occupant.

3. To provide systems for approximately locating the eyes of a vehicle driver to thereby permit the placement of the driver's eyes at a particular location in the vehicle.

4. To provide a pattern recognition system to permit more accurate location of an occupant's head and the parts thereof and to use this information to adjust a vehicle component.

5. To provide a method of determining whether a seat is occupied and, if not, leaving the seat at a neutral position.

6. To provide a system for automatically adjusting the position of various components of the vehicle to permit safer and more effective operation of the vehicle including the location of the pedals and steering wheel.

7. To determine whether an occupant is out-of-position relative to the airbag and if so, to suppress deployment of the airbag in a situation in which the airbag would otherwise be deployed.

8. To adjust the flow of gas into and/or out of the airbag based on the morphology and position of the occupant to improve the performance of the airbag in reducing occupant injury.

9. To provide a system where the morphological characteristics of an occupant are measured by sensors located within the seat.

10. To provide a system and method wherein the weight of an occupant is determined utilizing sensors located on the seat structure.

Further objects of the present invention will become apparent from the following discussion of the preferred embodiments of the invention.

## SUMMARY OF THE INVENTION

In one embodiment of an apparatus for measuring the weight of an occupying item of a seat, the apparatus includes at least one strain gage transducer, each mounted at a respective location on a support structure of the seat and arranged to provide a measurement of the strain of the support structure thereat. A control system is coupled to the strain gage transducer(s) for determining the weight of the occupying item of the seat based on the strain of the support structure measured by the strain gage transducer(s). The support structure of the seat is mounted to a substrate such as a floor pan of a motor vehicle. Electrical connection means such as wires connect the strain gage transducer(s) to the control system. Each strain gage transducer may incorporate signal conditioning circuitry and an analog to digital converter such that the measured strain is output as a digital signal.

The positioning of the strain gage transducer(s) depends in large part on the actual construction of the support structure of the seat. Thus, when the support structure comprises two elongate slide mechanisms adapted to be mounted on the substrate and support members for coupling the seat to the slide mechanisms, several strain gage transducers may be used, each arranged on a respective support member. If the support structure further includes a slide member, another strain gage transducer may be mounted thereon. Means for increasing the accuracy of the strain gage transducers are advantageous and include, for example, forming a support member from first and second tubes having longitudinally opposed ends and a third tube overlying the opposed ends of the first and second tubes and connected to the first and second tubes whereby a strain gage transducer is arranged on the third tube, Naturally, other structural shapes may be used in place of one or more of tie tubes.

In another embodiment of an apparatus for measuring the weight of an occupying item of a seat which includes slide mechanisms for mounting the seat to a substrate and bolts for mounting the seat to the slide mechanisms, the apparatus comprises at least one pressure sensor arranged between one of the slide mechanisms and the seat for measuring pressure exerted on the seat. Each pressure sensor may comprise first and second layers of shock absorbing material spaced from one another and a pressure sensitive material interposed between the first and second layers of shock absorbing material. A control system is coupled to the pressure sensitive material for determining the weight of the occupying item of the seat based on the pressure measured by the at least one pressure sensor. The pressure sensitive material may include an electrode on upper and lower faces thereof.

Another embodiment of an apparatus for measuring the weight of an occupying item of a seat includes a load cell adapted to be mounted to the seat and to a substrate on which the seat is supported. The load cell includes a member and a strain gage arranged thereon to measure tensile strain in the member caused by weight of an occupying item of the seat. A control system is coupled to the strain gage for determining the weight of an occupying item of the seat based on the strain in the member measured by the strain gage. If the member is a beam and the strain gage includes two strain sensing elements, then one strain sensing element is arranged in a longitudinal direction of the beam and the other is arranged in a transverse direction of the beam. If four strain sensing elements are present, a first pair is arranged in a longitudinal direction of the beam and a second pair is arranged in a transverse direction of the beam. The member may be a tube in which case, a strain sensing element is arranged on the tube to measure compressive strain in the tube and another strain sensing element is arranged on the tube to measure tensile strain in the tube. The member may also be an elongate torsion bar mounted at its ends to the substrate. In this case, the load cell includes a lever arranged between the ends of the torsion bar and connected to the seat such that a torque is imparted to the torsion bar upon weight being exerted on the seat. The strain gage thus includes a torsional strain sensing element.

The weight measuring apparatus described above may be used in apparatus and methods for adjusting a vehicle component, although other weight measuring apparatus may also be used in the vehicle component adjusting systems and methods described immediately below.

One embodiment of such an apparatus in accordance with invention includes a first measuring system for measuring a first morphological characteristic of the occupying item of the seat and a second measuring system for measuring a second morphological characteristic of the occupying item. Morphological characteristics include the weight of the occupying item, the height of the occupying item from the bottom portion of the seat and if the occupying item is a human, the arm length, head diameter and leg length. The apparatus also includes processor means for receiving the output of the first and second measuring systems and for processing the outputs to evaluate a seated-state based on the outputs. The measuring systems described herein, as well as any other conventional measuring systems, may be used in the invention to measure the morphological characteristics of the occupying item.

One preferred embodiment of an adjustment system in accordance with the invention includes a plurality of wave-receiving sensors for receiving waves from the seat and its contents, if any, and one or more weight sensors for detecting weight of an occupant in the seat or an absence of w eight applied onto the seat indicative of a vacant seat. The weight sensing apparatus may include strain sensors mounted on or associated with the seat structure such that the strain measuring elements respond to the magnitude of the weight of the occupying item. The apparatus also includes processor means for receiving the output of the wave-receiving sensors and the weight sensor(s) and for processing the outputs to evaluate a seated-state based on the outputs. The processor means then adjusts a part of the component or the component in its entirety based at least on the evaluation of the seated-state of the seat. The wave-receiving sensors may be ultrasonic sensors, optical sensors or electromagnetic sensors. If the wave-receiving sensors are ultrasonic or optical sensors, then they may also include transmitter means for transmitting ultrasonic or optical waves toward the seat.

If the component is a seat, the system includes power means for moving at least one portion of the seat relative to the passenger compartment and control means connected to the power means for controlling the power means to move the portion(s) of the seat. In this case, the processor means may direct the control means to affect the power means based at least in part on the evaluation of the seated-state of the seat. With respect to the direction or regulation of the control means by the processor means, this may take the form of a regulation signal to the control means that no seat adjustment is needed, e.g., if the seat is occupied by a bag of groceries or a child seat in a rear or forward-facing position as determined by the evaluation of the output from the ultrasonic or optical and weight sensors. On the other hand, if the processor means determines that the seat is occupied by an adult or child for which adjustment of the seat is beneficial or desired, then the processor means may direct the control means to affect the power means accordingly. For examples, if a child is detected on the seat, the processor means may be designed to lower the headrest.

In certain embodiments, the apparatus may include one or more sensors each of which measures a morphological characteristic of the occupying item of the seat, e.g., the height or weight of the occupying item, and the processor means are arranged to obtain the input from these sensors



and adjust the component accordingly. Thus, once the processor means evaluates the occupancy of the seat and determines that the occupancy is by an adult or child, then the processor means may additionally use either the obtained weight measurement or conduct additional measurements of morphological characteristics of the adult or child occupant and adjust the component accordingly. The processor means may be a single microprocessor for performing all of the functions described above. In the alternative, one microprocessor may be used for evaluating the occupancy of the seat and another for adjusting the component.

The processor means may comprise an evaluation circuit implemented in hardware as an electronic circuit or in software as a computer program.

In certain embodiments, a correlation function or state between the output of the various sensors and the desired result (i.e., seat occupancy identification and categorization) is determined, e.g., by a neural network that may be implemented in hardware as a neural computer or in software as a computer program. The correlation function or stale that is determined by employing this neural network may also be contained in a microcomputer. In this case, the microcomputer can be employed as an evaluation circuit. The word circuit herein will be used to mean both an electronic circuit and the functional equivalent implemented on a microcomputer using software.

In enhanced embodiments, a heart beat sensor may be provided for detecting the heart beat of the occupant and generating an output representative thereof. The processor means additionally receive this output and evaluate the seated-state of the seat based in part thereon. In addition to or instead of such a heart beat sensor, a capacitive sensor and/or a motion sensor may be provided. The capacitive sensor detects the presence of the occupant and generates an output representative of the presence of the occupant. The motion sensor detects movement of the occupant and generates an output representative thereof. These outputs are provided to the processor means for possible use in the evaluation of the seated-state of the seat.

The portion of the apparatus which includes the ultrasonic, optical or electromagnetic sensors, weight measuring means and processor means which evaluate the occupancy of the seat based on the measured weight of the seat and its contents and the returned waves from the ultrasonic, optical or electromagnetic sensors may be considered to constitute a seated-state detecting unit.

The seated-state detecting unit may further comprise a seat track position-detecting sensor. This sensor determines the position of the seat on the seat track in the forward and aft direction. In this case, the evaluation circuit evaluates the seated-state, based on a correlation function obtain from outputs of the ultrasonic sensors, an output of the one or more weight sensors, and an output of the seat track position detecting sensor. With this structure, there is the advantage that the identification between the flat configuration of a detected surface in a state where a passenger is not sitting in the seat and the flat configuration of a detected surface which is detected when a seat is slid backwards by the amount of the thickness of a passenger, that is, of identification of whether a passenger seat is vacant or occupied by a passenger, can be reliably performed.

Furthermore, the seated-state detecting unit may also comprise a reclining angle detecting sensor, and the evaluation circuit may also evaluate the seated-state based on a correlation function obtained from outputs of the ultrasonic, optical or electromagnetic sensors, an output of the weight

sensor(s), and an output of the reclining angle detecting sensor. In this case, if the tilted angle information of the back portion of the seat is added as evaluation information for the seated-state, identification can be clearly performed between the flat configuration of a surface detected when a passenger is in a slightly slouching state and the configuration of a surface detected when the back portion of a seat is slightly tilted forward and similar difficult-to-discriminate cases. This embodiment may even be combined with the output from a seat track position-detecting sensor to further enhance the evaluation circuit.

Moreover, the seated-state detecting unit may further comprise a comparison circuit for comparing the output of the weight sensor(s) with a reference value. In this case, the evaluation circuit identifies an adult and a child based on the reference value.

Preferably, the seated-state detecting unit comprises: a plurality of ultrasonic, optical or electromagnetic sensors for transmitting ultrasonic or electromagnetic waves toward a seat and receiving reflected waves from the seat; one or more weight sensors for detecting weight of a passenger in the seat, a seat track position detecting sensor; a reclining angle detecting sensor; and a neural network circuit to which outputs of the ultrasonic or electromagnetic sensors and the weight sensor(s), an output of the seat track position detecting sensor, and an output of the reclining angle detecting sensor are inputted and which evaluates several kinds of seated-states, based on a correlation function obtained from the outputs.

The kinds of seated-states that can be evaluated and categorized by the neural network include the following categories, among others, (i) a normally seated passenger and a forward facing child seat, (ii) an abnormally seated passenger and a rear-facing child seat, and (iii) a vacant seat.

The seated-state detecting unit may further comprise a comparison circuit for comparing the output of the weight sensor(s) with a reference value and a gate circuit to which the evaluation signal and a comparison signal from the comparison circuit are input. This gate circuit, which may be implemented in software or hardware, outputs signals which evaluates several kinds of seated-states. These kinds of seated-states can include a (i) normally seated passenger, (ii) a forward facing child seat, (iii) an abnormally seated passenger, (iv) a rear facing child seat, and (v) a vacant seat. With this arrangement, the identification between a normally seated passenger and a forward facing child seat, the identification between an abnormally seated passenger and a rear facing child seat, and the identification of a vacant seat can be more reliably performed.

The outputs of the plurality of ultrasonic or electromagnetic sensors, the output of the weight sensor(s), the outputs of the seat track position detecting sensor, and the outputs of the reclining angle detecting sensor are inputted to the neural network or other pattern recognition circuit, and the neural network circuit determines the correlation function, based on training thereof during a training phase. The correlation function is then typically implemented in or incorporated into a microcomputer. For the purposes herein, neural network will be used to include both a single neural network, a plurality of neural networks, and other similar pattern recognition circuits or algorithms and combinations thereof including the combination of neural networks and fuzzy logic systems such as neural-fuzzy systems.

To provide the input from the ultrasonic or electromagnetic sensors to the neural network circuit, it is preferable that an initial reflected wave portion and a last reflected wave portion are removed from each of the reflected waves of the ultrasonic or electromagnetic sensors and then the output data is processed. This is a form of range gating. With this arrangement, the portions of the reflected ultrasonic or electromagnetic wave that do not contain useful information are removed from the analysis and the presence and recognition of an object on the passenger seat can be more accurately performed.

The neural network circuit determines the correlation function by performing a weighting process, based on output data from the plurality of ultrasonic or electromagnetic sensors, output data from the weight sensor(s), output data from the seat track position detecting sensor if present, and/or on output data from the reclining angle detecting sensor if present. Additionally, in advanced systems, outputs from the heartbeat and occupant motion sensors may be included.

In a disclosed method for determining the occupancy of a seat in a passenger compartment of a vehicle in accordance with the invention, waves such as ultrasonic or electromagnetic waves are transmitted into the passenger compartment toward the seat, reflected waves from the passenger compartment are received by a component which then generates an output representative thereof, the weight applied onto the seat is measured and an output is generated representative thereof and then the seated-state of the seat is evaluated based on the outputs from the sensors and the weight measuring means.

The evaluation the seated-state of the seat may be accomplished by generating a function correlating the outputs representative of the received reflected waves and the measured weight and the seated-state of the seat, and incorporating the correlation function into a microcomputer. In the alternative, it is possible to generate a function correlating the outputs representative of the received reflected waves and the measured weight and the seated-state of the seat in a neural network circuit, and execute the function using the outputs representative of the received reflected waves and the measured weight as input into the neural network circuit.

To enhance the seated-state determination, the position of a seat track of the seat is measured and an output representative thereof is generated, and then the seated-state of the seat is evaluated based on the outputs representative of the received reflected waves, the measured weight and the measured seat track position. In addition to or instead of measuring the seat track position, it is possible to measure the reclining angle of the seat, i.e., the angle between the seat portion and the back portion of the seat, and generate an output representative thereof, and then evaluate the seated-state of the seat based on the outputs representative of the received reflected waves, the measured weight and the measured reclining angle of the seat (and seat track position, if measured).

Furthermore the output representative of the measured weight may be compared with a reference value, and the occupying object of the seat identified, e.g., as an adult or a child, based on the comparison of the measured weight with the reference value.

In additional embodiments, the present invention involves the measurement of one or more morphological characteristics of a vehicle occupant and the use of these measurements to classify the occupant as to size and weight, and then to use this classification to position a vehicle component, such as the seat, to a near optimum position for that class of occupant. Additional information concerning occupant preferences can also be associated with the occupant class so that

when a person belonging to that particular class occupies tie vehicle, the preferences associated with that class are implemented. These preferences and associated component adjustments include the seat location after it has been manually adjusted away from the position chosen initially by the system, the mirror location, temperature, radio station, steering wheel and steering column positions, etc. The preferred morphological characteristics used are the occupant height from the vehicle seat and weight of the occupant. The height is determined by sensors, usually ultrasonic or electromagnetic, located in the headrest or another convenient location. The weight is determined by one of a variety of technologies that measure either pressure on or displacement of the vehicle seat or the force or strain in the seat supporting structure.

## BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of embodiments of the invention and are not meant to limit the scope of the invention as encompassed by the claims.

FIG. 1 shows a seated-state detecting unit in accordance with the present invention and the connections between ultrasonic or electromagnetic sensors, a weight sensor, a reclining angle detecting sensor, a seat track position detecting sensor, a heartbeat sensor, a motion sensor, a neural network circuit, and an airbag system installed within a vehicle compartment;

FIG. 2 is a perspective view of a vehicle showing the position of the ultrasonic or electromagnetic sensors relative to the driver and front passenger seats.

FIG. 3 is a circuit diagram of the seated-state detecting unit of the present invention;

FIGS. 4(*a*), 4(*b*) and 4(*c*) are each a diagram showing the configuration of the reflected waves of an ultrasonic wave transmitted from each transmitter of the ultrasonic sensors toward the passenger seat, obtained within the time that the reflected wave arrives at a receiver, FIG. 4(*a*) showing an example of the reflected waves obtained when a passenger is in a normal seated-state, FIG. 4(*b*) showing an example of the reflected waves obtained when a passenger is in an abnormal seated-state (where the passenger is seated too close to the instrument panel), and FIG. 4(*c*) showing a transmit pulse;

FIG. 5 is a diagram of the data processing of the reflected waves from the ultrasonic or electromagnetic sensors;

FIG. 6 is a flowchart showing the training steps of a neural network circuit;

FIG. 7(*a*) is an explanatory diagram of a process for normalizing the reflected wave and shows normalized reflected waves; and

FIG. 7(*b*) is a diagram similar to FIG. 7(*a*) showing a step of extracting data based on the normalized reflected waves and a step of weighting the extracted data by employing the data of the seat track position detecting sensor, the data of the reclining angle detecting sensor, and the data of the weight sensor.

FIG 8 is a perspective view of an automatic seat adjustment system, with the seat shown in phantom, with a movable headrest and sensors for measuring the height of the occupant from the vehicle seat showing motors for moving the seat d a control circuit connected to the sensors and motors.

FIG. 9 is a perspective view of the seat shown in FIG. 8 with the addition of a weight sensor shown mounted onto the seat.

FIG. 9A is a view taken along line 9A—9A in FIG. 9.

FIG. 9B is an enlarged view of the section designated 9B in FIG. 9A.

FIG. 10 is a side plan view of the interior of an automobile, with portions cut away and removed, with two occupant height measuring sensors, one mounted into the headliner above the occupant's head and the other mounted onto the A-pillar and also showing a seatbelt associated with the seat wherein the seatbelt has an adjustable upper anchorage point which is automatically adjusted based on the height of the occupant.

FIG. 11 is a view of the seat of FIG. 8 showing motors for changing the tilt of seat back and the lumbar support.

FIG. 12 is a view of the seat of FIG. 8 showing a system for changing the stiffness and the damping of the seat.

FIG. 13 is a view as in FIG. 10 showing a driver and driver seat with an automatically adjustable steering column and pedal system which is adjusted based on the morphology of the driver.

FIG. 14 is a perspective view of the interior of the passenger compartment of an automobile, with parts cut away and removed, showing a variety of transmitters that can be used in a phased array system.

FIG. 15 is a view similar to FIG. 8 showing the occupant's eyes and the seat adjusted to place the eyes at a particular vertical position for proper viewing through the windshield and rear view mirror.

FIG. 16 is a view similar to FIG. 8 showing an inflated airbag and an arrangement for controlling both the flow of gas into and the flow of gas out of the airbag during the crash where the determination is made based on a height sensor located in the headrest and a weight sensor in the seat.

FIG. 17A is a schematic drawing of the basic embodiment of the adjustment system in accordance with the invention.

FIG. 17B is a schematic drawing of another basic embodiment of the adjustment system in accordance with the invention.

FIG. 18 is a perspective view of a one embodiment of an apparatus for measuring the weight of an occupying item of a seat illustrating weight sensing transducers mounted on a seat control mechanism portion which is attached directly to the seat.

FIG. 19 illustrates a seat structure with the seat cushion and back cushion removed illustrating a three slide attachment of the seat to the vehicle and preferred mounting locations on the seat structure for strain measuring weight sensors of an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention.

FIG 19A illustrates an alternate view of the seat structure transducer mounting location taken in the circle A of FIG. 19 FIG. with the addition of a gusset and where the strain gage is mounted onto the gusset.

FIG. 19B illustrates a mounting location for a weight sensing transducer on a centralized transverse support member in an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention.

FIGS. 20A–20C illustrate three alternate methods of mounting strain transducers of an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention on1to a tubular seat support structural member.

FIG. 21 illustrates an alternate weight sensing transducer utilizing pressure sensitive transducers.

FIG. 22 illustrates an alternate seat structure assembly utilizing strain transducers.

FIG. 22A is a perspective view of a cantilevered beam type load cell for use with the weight measurement system of this invention for mounting locations of FIG. 22, for example.

FIG. 22B is a perspective view of a simply supported beam type load cell for use with the weight measurement system of this invention as an alternate to the cantilevered load cell of FIG. 22A.

FIG. 22C is an enlarged view of the portion designated 22C in FIG. 22B.

FIG. 22D is a perspective view of a tubular load cell for use with the weight measurement system of this invention as an alternate to the cantilevered load cell of FIG. 22A.

FIG. 22E is a perspective view of a torsional beam load cell for use with the weight measurement apparatus in accordance with the invention as an alternate to the cantilevered load cell of FIG. 22A.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the accompanying drawings wherein like reference numbers designate the same or similar elements. FIG. 1 shows a passenger seat 1 to which an adjustment apparatus including a seated-state detecting unit according to the present invention may be applied. The seat 1 includes a horizontally situated bottom seat portion 2 and a vertically oriented back portion 3. The seat portion 2 is provided with one or more weight sensors 6 and 7 that determine the weight of the object occupying the seat. The coupled portion between the seated portion 2 and the back portion 3 is provided with a reclining angle detecting sensor 9, which detects the tilted angle of the back portion 3 relative to the seat portion 2. The seat portion 2 is provided with a seat track position-detecting sensor 10. The seat track position detecting sensor 10 fulfills a role of detecting the quantity of movement of the seat 1 which is moved from a back reference position, indicated by the dotted chain line. Embedded within the seatback is a heartbeat sensor 31 and a motion sensor 33. Attached to the headliner is a capacitance sensor 32. The seat 1 may be the driver seat, the front passenger seat or any other seat in a motor vehicle as well as other seats in transportation vehicles or seats in non-transportation applications.

Weight measuring means such as the sensors 6 and 7 are associated with the seat, e.g., mounted into or below the seat portion 2 or on the seat structure, for measuring the weight applied onto the seat. The weight may be zero if no occupying item is present. Sensors 6 and 7 may represent a plurality of different sensors which measure the weight applied onto the seat at different portions thereof or for redundancy purposes, e.g., such as by means of an airbag 7 in the seat portion 2. Such sensors may be in the form of strain, force or pressure sensors which measure the force or pressure on the seat or seat back, displacement measuring sensors which measure the displacement of the seat surface or the entire seat such as through the use of strain gages mounted on the seat structural members, such as 7, or other appropriate locations, or systems which convert displacement into a pressure wherein a pressure sensor can be used as a measure of weight.

As shown in FIG. 2, there are provided four sets of wave-receiving sensor systems 11–14 mounted within the passenger compartment. Each set of sensor systems 11–14 comprises a transmitter and a receiver, which may be integrated into a single unit or individual components separated from one another. In this embodiment, the sensor system 11 is mounted on the upper portion of the front pillar, A-Pillar, of the vehicle. The sensor system 12 is mounted on the upper portion of the intermediate pillar, B-Pillar. The sensor system 13 is mounted on the roof ceiling portion or the headliner (FIG. 2). The sensor system 14 is mounted near the middle of an instrument panel 17 in front of the driver's seat 16 (FIG. 2). The sensor systems are preferably ultrasonic or electromagnetic. Although sensor systems 11–14 are described as being ultrasonic or electromagnetic sensors, the invention is equally applicable for other types of sensors (other than ultrasonic or electromagnetic) which will detect the presence of an occupant from a distance including Capacitive sensors. Also, if the sensor systems 11–14 are passive infrared sensors, then they may only comprise a wave-receiver.

The ultrasonic or electromagnetic sensor systems 11–14 are controlled or driven, one at a time or simultaneously, by an appropriate driver circuit such as ultrasonic or electromagnetic sensor driver circuit 18 shown in FIG. 3. The transmitters of the ultrasonic or electromagnetic sensor systems 11–14 transmit respective ultrasonic or electromagnetic waves toward the seat 1 and transmit pulses (see FIG. 4(*c*)) in sequence at times t1, t2, t3 and t4 (t4>t3>t2>t1) or simultaneously (t1=t2=t3=t4). The reflected waves of the ultrasonic or electromagnetic waves are received by the receivers ChA–ChD of the ultrasonic or electromagnetic sensors 11–14. The receiver ChA is associated with the ultrasonic or electromagnetic sensor system 13, the receiver ChB is associated with the ultrasonic or electromagnetic sensor system 14, the receiver ChD is associated with the ultrasonic or electromagnetic sensor system 11, and the receiver ChD is associated with the ultrasonic or electromagnetic sensor system 12.

The following discussion will apply to the case where ultrasonic sensors are used although a similar discussion can be presented relative to the use of electromagnetic sensors such as active infrared sensors, taking into account the differences in the technologies. Also, the following discussion will relate to an embodiment wherein the seat 1 is the front passenger seat. FIGS. 4(*a*) and 4(*b*) show examples of the reflected ultrasonic waves USRW that are received by receivers ChA–ChD. FIG. 4(*a*) shows an example of the reflected wave USRW that is obtained when an adult sits in a normally seated space on the passenger seat 1, while FIG. 4(*b*) shows an example of the reflected wave USRW that are obtained when an adult sits in a slouching state (one of the abnormal seated-states) in the passenger seat 1.

In the case of a normally seated passenger, as shown in FIG. 2, the location of the ultrasonic sensor system 12 is closest to the passenger A. Therefore, the reflected wave pulse P1 is received earliest after transmission by the receiver ChD as shown in FIG. 4(*a*), and the width of the reflected wave pulse P1 is larger. Next, the distance from the ultrasonic sensor 13 is closer to the passenger A, so a reflected wave pulse P2 is received earlier by the receiver ChA compared with the remaining reflected wave pulses P3 and P4 . Since the reflected wave pauses P3 and P4 take more time than the reflected wave pulses P1 and P2 to arrive at the receivers ChC and ChB, the reflected wave pulses P3 and P4 are received as the timings shown in FIG. 4(*a*). More specifically, since it is believed that the distance from the ultrasonic sensor system 11 to the passenger A is slightly shorter than the distance from the ultrasonic sensor system 14 to the passenger A, the reflected wave pulse P3 is received slightly earlier by the receiver ChC than the reflected wave pulse P4 is received by the receiver ChB.

In the case where the passenger A is sitting in a slouching state in the passenger seat 1, the distance between the

ultrasonic sensor system 11 and the passenger A is shortest. Therefore, the time from transmission at time t3 to reception is shortest, and the reflected wave pulse P3 is received by the receiver ChC, as shown in FIG. 4(*b*). Next, the distances between the ultrasonic sensor system 14 and the passenger A becomes shorter, so the reflected wave pulse P4 is received earlier by the receiver ChB than the remaining reflected wave pulses P2 and P1. When the distance from the ultrasonic sensor system 13 to the passenger A is compared with that from the ultrasonic sensor system 12 to the passenger A, the distance from the ultrasonic sensor system 13 to the passenger A becomes shorter, so the reflected wave pulse P2 is received by the receiver ChA first and the reflected wave pulse P1 is thus received last by the receiver ChD.

The configurations of the reflected wave pulses P1–P4, the times that the reflected wave pulses P1–P4 are received, the sizes of the reflected wave pulses P1–P4 are varied depending upon the configuration and position of an object such as a passenger situated on the front passenger seat 1. FIGS. 4(*a*) and (*b*) merely show examples for the purpose of description and therefore it is a matter of course that the present invention is lot limited to these examples.

The outputs of the receivers ChA–ChD, as shown in FIG. 3, are input to a band pass filter 20 through a multiplex circuit 19 which is switched in synchronization with a timing signal from the ultrasonic sensor drive circuit 18. The band pass filter 20 removes a low frequency wave component from the output signal based on each of the reflected wave USRW and also removes some of the noise. The output signal based on each of the reflected wave USRW is passed through the band pass filter 20, then is amplified by an amplifier 21. The amplifier also removes the high frequency carrier wave component in each of the reflected USRW and generates an envelope wave signal. This envelope wave signal is input to an analog/digital converter (ADC) 22 and digitized as measured data. The measured data is input to a processing circuit 23, which is controlled by the timing signal which is in turn output from the ultrasonic sensor drive circuit 18.

The processing circuit 23 collects measured data at intervals of 7 ms, and 47 data points are generated for each of the ultrasonic sensor systems 11–14. For each of these reflected waves USRW, the initial reflected wave portion T1 and the last reflected wave portion T2 are cut off. The reason for this will be described when the training procedure of a neural network circuit is described later, and the description is omitted for now. With this, 32 data points, 31 data points, 37 data points, and 38 data points will be sampled by the ultrasonic sensor systems 11, 12, 13 and 14, respectively. The reason why the number of data points differs for each of the ultrasonic sensor systems 11–14 is that the distance from the passenger seat 1 to the ultrasonic sensor systems 11–14 differ from one another.

Each of the measured data is input to a normalization circuit 24 and normalized. The normalized measured data is input to the neural network circuit 25 as wave data.

The output of the weight sensor(s) 6 and 7 is amplified by an amplifier 26 coupled to the weight sensor(s) 6 and 7 and the amplified output is input to the analog/digital converter 27.

The reclining angle detecting sensor 9 and the seat track position-detecting sensor 10, which each may comprise a variable resistor, are connected to constant-current circuits, respectively. A constant-current is supplied from the constant-current circuit to the reclining angle detecting sensor 9, and the reclining angle detecting sensor 9 converts a change in the resistance value on the tilt of the back portion 3 to a specific voltage. This output voltage is input to an analog/digital converter 28 as angle data, i.e., representative of the angle between the back portion 3 and the seat portion 2. Similarly, a constant current is supplied from the constant-current circuit to the seat track position detecting sensor 10 and the seat track position detecting sensor 10 converts a change in the resistance value based on the track position of the seat portion 2 to a specific voltage. This output voltage is input to an analog/digital converter 29 as seat track data. Thus, the outputs of the reclining angle-detecting sensor 9 and the seat track position-detecting sensor 10 are input to the analog/digital converters 28 and 29, respectively. Each digital data value from the ADCs 28,29 is input to the neural network circuit 25. Although the digitized data of the weight sensor(s) 6 and 7 is input to the neural network circuit 25, the output of the amplifier 26 is also input to a comparison circuit. The comparison circuit, which is incorporated in the gate circuit algorithm, determines whether or not the weight of an object oil the passenger seat 1 is more than a predetermined weight, such as 60 lbs., for example. When the weight is more than 60 lbs., the comparison circuit outputs a logic 1 to the gate circuit to be described later. When the weight of the object is less than 60 lbs, a logic 0 is output to the gate circuit.

A heartbeat sensor 31 is arranged to detect a heart beat, and the magnitude thereof, of a human occupant of the seat, if such a human occupant is present. The output of the heart beat sensor 31 is input to the neural network circuit 25. The heartbeat sensor 31 may be of the type as disclosed in McEwan (U.S. Pat. Nos. 5,573,012 and 5,766,208 which are included herein in their entirety by reference). The heartbeat sensor 31 can be positioned at any convenient position relative the seat 1 where occupancy is being monitored. A preferred location is within the vehicle seatback.

A capacitive sensor 32 is arranged to detect the presence of an occupying item on the seat 1 and the output thereof is input to the neural network circuit 25. Capacitor sensors appropriate for this function are disclosed in Kithil (U.S. Pat. No. 5,602,734 which is included herein by reference). Capacitive sensors can in general be mounted at locations 11–14 in FIG. 2 or as shown in FIG. 1.

A motion sensor 33 is arranged to detect motion of an occupying item on the seat 1 and the output thereof is input to the neural network circuit 25. Motion sensors can utilize a micro-power impulse radar (MIR) system as disclosed, for example, in McEwan (U.S. Pat. No. 5,361,070, which is included herein by reference), as well as many other patents by the same inventor. Motion sensing is accomplished by monitoring a particular range from the sensor as disclosed in that patent. MIR is one form of radar which has applicability to occupant sensing and can be mounted at locations such as 11–14 in FIG. 2. It has an advantage over ultrasonic sensors in that data can be acquired at a higher speed and thus the motion of an occupant can be more easily tracked. The ability to obtain returns over the entire occupancy range is somewhat more difficult than with ultrasound resulting in a more expensive system overall. MIR has additional advantages in lack of sensitivity to temperature variation and has a comparable resolution to about 40 kHz ultrasound. Resolution comparable to higher frequency is feasible but has not been demonstrated. Additionally, multiple MIR sensors can be used when high speed tracking of the motion of an occupant during a crash is required since they can be individually pulsed without interfering with each through time division multiplexing.